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A Discussion of Propeller Efficiency*

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Presented at the Aerodynamics Session, Seventh Annual Meeting, I. Ae. S. January 27, 1939

SUMMARY

The results of a survey concerning most of the conventional, radial-engine powered airplanes in this country on which complete wind-tunnel drag breakdowns have been made and are available are presented in Part I. Values of "propulsive efficiencies" submitted varied from 73 to 149 percent. The "propulsive" efficiencies that are within reasonable limits are shown to vary directly in proportion to the percentage of nacelle drag (including cooling) to the total airplane drag. A method is presented showing how it is possible to effectively and accurately use "net" propeller efficiencies to check the level flight performance of an airplane by applying "net" efficiencies, corrected for tip speed, to the drag coefficients of the complete airplane less engine nacelles.

A secondary but important result of this study, included in Part II, gives a realization of the great improvement in performance that can be expected in the next several years as the result of enclosing the engines within the airplane or wing structure and driving the propellers by extension shafts. The reduction in drag, the increase in lift, L/D ratio and propeller efficiency associated with extension shaft drives give for equal powers a considerable improvement in all operating velocities, a substantially increased range and appreciably slower landing velocities. For extension shafts drives, whether tractor or pusher, the propeller efficiencies needed will be the "isolated" propeller efficiencies. "Isolated" propeller working charts of a series of five three-blade propellers with several pitch distributions are presented.

Part III comprises short paragraphs of discussion of trends and indications concerning propeller tip speed corrections and the benefits that may be derived from propeller blade shank fairings are included.

PART I

SEVERAL years ago the author was associated with a group of aerodynamicists, each of whom applied his own empirical correction factor to the propulsive efficiencies most commonly accepted as standard as published in reference 1. These correction factors had been determined by experience over several years by comparing the predicted performance of airplanes from wind-tunnel tests with the measured full flight performance. These factors now vary with the individual from .85 to .92 and are used to correct the chart values of reference 1 and later pertinent N.A.C.A. reports. In an effort to satisfactorily explain these various factors a study was made of performance reports that had been submitted to the Materiel Division. This study showed a trend that the percentage $(C_{D_{P_N}}/C_{D_T})$ of parasite nacelle drag (including engine cooling) to the total airplane drag varied more or less directly with the propeller efficiency adjusted to agree with flight tests. A study of reference 2 confirms the results of this study.

Several nose cowling shapes were tested on an air-cooled, radial engine nacelle in combination with several propellers in this investigation.[2] The most critical nose shape, No. 1 (reference 2), gave "propulsive" efficiencies† as high as 130 percent. This shape, however, gave a "net" efficiency of only 68 percent. More representative cowling shapes gave "propulsive" efficiencies averaging about 85 percent and "net" efficiencies of about 70 percent. The propeller alone (isolated) gives efficiencies as high as 81 percent (see accompanying charts, Figs. 6–10). The isolated propeller is working under as near ideal conditions as possible. Whenever

* The views expressed in this report are those of the author and not necessarily those of the War Department.

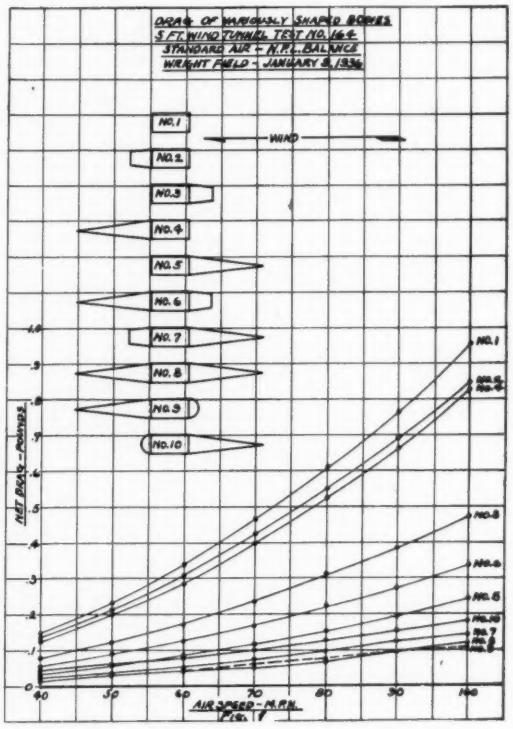
† The various propeller efficiencies used are given in the Appendix.

the efficiency of the propeller, working in combination with an engine nacelle, greatly exceeds that for the propeller alone, it usually means that the propeller slip stream has decreased the drag of the nacelle and its cowling below that for the nacelle alone, as tested at the same free stream velocity and without the propeller. The "net" efficiency is always below that for the propeller alone because of the drag of the nacelle. Reference 2 shows that those nose cowling shapes which give the highest "propulsive" efficiency do not necessarily give the highest "net" efficiency (see, for instance, nose No. 1, reference 2).

"Propulsive" efficiency is that efficiency commonly used is computing the performance of an airplane whose drag coefficients have been determined from model wind-tunnel tests. This efficiency is used for the entire airplane in determining the power available. Models are usually tested without propellers. It has been explained[2] that the propeller slip stream improves the drag of a radial-engined nacelle by reducing the peak of negative pressure of the nose of the cowling. It does not, however, improve the drag of the entire airplane and even has an adverse effect on the other parts of the structure, such as the wing and tail, that are aft of the propeller. Therefore, it is difficult to see how the aerodynamicist can evaluate and apply propeller efficiencies greater than those for the isolated propeller. As stated, "propulsive" efficiencies are now commonly corrected empirically to bring their values down to reasonable limits. It is later shown how it is possible to use "net" efficiencies for level flight performance calculations without the need of empirical correction factors. The adverse drag effect of the slip stream is evaluated by correcting the airplane drag.

In order to gain a further appreciation of the effects of a propeller slip stream on an afterbody, the results of wind-tunnel drag tests carried out on the Materiel Division on several simple bodies of revolution are shown in Fig. 1. Probably the most surprising results are those for Nos. 4 and 5. Body No. 4 has $3^1/_3$ times the drag of No. 5 due largely to the high negative pressure at the sharp leading edge. The optimum body is No. 9. A propeller slip stream imposed on body No. 4 would scavenge the breakdown at the leading edge and smooth out the flow, giving a reduction in drag. The propeller would have a propulsive efficiency appreciably in excess of that of the isolated propeller. The same slip stream on body No. 5 would add to the drag slightly and the propulsive efficiency would be less than that for the isolated propeller. (See page 146, reference 3.) The net drag, however, would be less and the net propeller efficiency for body No. 5 would still be greater than for body No. 4.

It seems reasonable to use "net" propeller efficiencies applied to the drag coefficient of the airplane (less nacelles) and to evaluate the effect of the added drag due to the propeller slip stream of the wing and tail. "Propulsive" efficiencies that are determined with full scale propellers under full scale operating conditions present truer values than those drag coefficients which it is possible to obtain on a small scale airplane model in a wind tunnel. It is believed that the airplane drag coefficients rather than the "propulsive" efficiency should be corrected. Of the variables in the flight performance equation more is known quantitatively about the propeller than about any other variable. For years aerodynamicists have been prone to group all of the unknown variations in horsepower, Reynolds Number, slip stream drag, cooling drag, tip speed effects, etc., into propulsive efficiency because it was convenient to do so. As a result the corrections required varied widely between different individuals and companies. As long as these correction factors were confined to one manufacturer's records the discrepancies were not serious. When, however, manufacturers send data to a central agency, such as the Materiel Division, and an attempt is made to evaluate the relative performance of the airplanes submitted, it becomes very difficult to correlate contradictory values of the several variables.



In one instance, data on three airplanes, all of about equal performance, using identical engines, propellers, and with practically identical engine cowling, were submitted and the propulsive efficiencies varied from 69 to 86 percent. The airplane performances checked within the accepted flight test accuracy of ± 1 percent. In addition all three airplanes had been model tested in

TABLE 1

DRAG BREAKDOWN DATA

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
No.	C_{D_i}	C_{D_0}	C_{D_p}	C_{D_T}	$C_{D_{P_N}}$	$\frac{C_{D_{P_N}}}{C_{D_T}}$	η	$C_{D_{T_N}}$	No. Engines	Corr. Factor $C_{D_{T_N}}$	$C_{D_{T_N}}$ Corr.	η_n	Helical Tip Speed	Eff. Factor	η Corr.	V/V_n	W.T.	Remarks
1	.0012	.0093	.0125	.0230	.0026	.113	.730	.0204	2	1.06	.0216	.70	985	.965	.675	1.005	A	Conventional Land Plane
2	.0020	.0106	.0084	.0210	.0027	.129	.730	.0183	2	1.06	.0194	.70	940	.990	.695	.990	A	Conventional Land Plane
3	.0023	.0097	.0113	.0233	.0027	.116	.730	.0206	2	1.06	.0218	.70	990	.960	.670	1.006	A	Conventional Land Plane
4	.0025	.0100	.0142	.0267	.0051	.191	.755	.0216	2	1.06	.0229	.70	1055	.920	.645	1.001	A	Conventional Land Plane
5	.0025	.0100	.0150	.0275	.0065	.236	.805	.0210	2	1.06	.0223	.70	1000	.955	.670	.992	A	Conventional Land Plane
6	.0050	.0120	.0120	.0290	.0030	.103	.750	.0260	2	1.06	.0276	.70	985	.960	.670	1.021	A	Flying Boat—Conventional Nacelles (est.)
7	.0015	.0100	.0160	.0275	.0033	.120	.730	.0242	2	1.06	.0256	.70	995	.950	.665	1.007	A	Flying Boat—Conventional Nacelles (est.)
8	.0038	.0113	.0216	.0367	.0075	.204	.790	.0292	2	1.02	.0298	.63	850	1.000	.630	1.006	A	Amphibian — Nacelles above Wing
9	.0014	.0097	.0139	.0250	.0080	.320	.860	.0170	4	1.10	.0187	.70	1010	.950	.665	.990	A	Conventional Land Plane
10	.0021	.0082	.0157	.0260	.0076	.292	.855	.0184	4	1.10	.0202	.70	1010	.950	.665	1.000	A	Conventional Land Plane (Est. Not Yet Flown)
11	.0025	.0116	.0181	.0322	.0038	.122	.730	.0284	4	1.10	.0312	.70	955	.985	.690	1.008	A	Conventional Land Plane
12	.0024	.0081	.0108	.0213	.0042	.197	.780		4								B	Conventional Land Plane ($C_{D_{P_N}}$ Est.)
13	.0044	.0081	.0198	.0323	.0047	.145	.855		4								C	Conventional Land Plane
14	.0044	.0127	.0290	.0461	.0067	.145	.820		4								D	Flying Boat—Conventional Nacelles
15	.0030	.0100	.0254	.0384	.0058	.151	.820		2								D	Amphibian — Conventional Nacelles
16	.0020	.0098	.0261	.0379	.0059	.156	.850		2								E	Conventional Land Plane
17	.0026	.0100	.0230	.0356	.0089	.250	.750		2								F	Conventional Land Plane
18	.0030	.0100	.0340	.0470	.0100	.213	1.490		2								G	Conventional Land Plane
19	.0032	.0090	.0287	.0409	.0069	.168	.695		1								H	Amphibian — Nacelle above Wing

the same wind tunnel. This latter apparently eliminated the objection that the drag coefficients might be at fault. There were no published data to explain the discrepancies in propulsive efficiency.

This led the author to send a questionnaire to the manufacturers in this country of airplanes with air-cooled, radial engines in an attempt to accumulate enought data to permit the construction of quantitative curves that could be used for design purposes. Unfortunately, only a comparatively few models had been so tested that a drag breakdown including the nacelle and cooling drag could be made. From Table 1 it can be seen that only one wind tunnel (A) makes a standard practice of obtaining these drag breakdowns. The results of this questionnaire are presented in columns 1 to 8, inclusive, Table 1, in the exact form received. No corrections have been made to the data submitted. The number of models is small but represents the majority of pertinent data available at this time and all of that submitted.

Discussion of Data

Following are definitions of the coefficients and factors that occur in the various columns. All data concern only the high-speed condition for the various models.

C_{D_i}—induced drag coefficient

C_{D_0}—profile drag coefficient

C_{D_p}—parasite drag coefficient

C_{D_T}—total airplane drag coefficient = $C_{D_i} + C_{D_0} + C_{D_p}$

$C_{D_{P_N}}$—engine nacelle parasite drag coefficient including cooling

$C_{D_{P_N}}/C_{D_T}$—percentage of nacelle drag to total airplane drag

η—propulsive efficiency (from actual $V_{max.}$ and $W.T.$ C_{D_T})

$C_{D_{T_n}}$—net airplane drag coefficient = $C_{D_T} - C_{D_{P_N}}$ (airplane drag less nacelle and cooling drag)

Correction factor for $C_{D_{T_n}}$—Added drag due to propeller slip stream — 2 percent for each propeller blowing over wing; 1 percent additional for each propeller blowing over tail. (See reference 3, page 154.)

Column 12—Column 9 times Column 11

η_n—net propeller efficiency as determined from reference 2

Helical tip speed—effective helical tip speed corrected for speed of sound to sea level

Efficiency factor—tip speed correction factor Fig. 2

V/V_n—ratio of change in performance

V—maximum velocity using "propulsive" efficiency

V_n—maximum velocity using "net" efficiency

W.T.—wind tunnel in which drag coefficients were determined

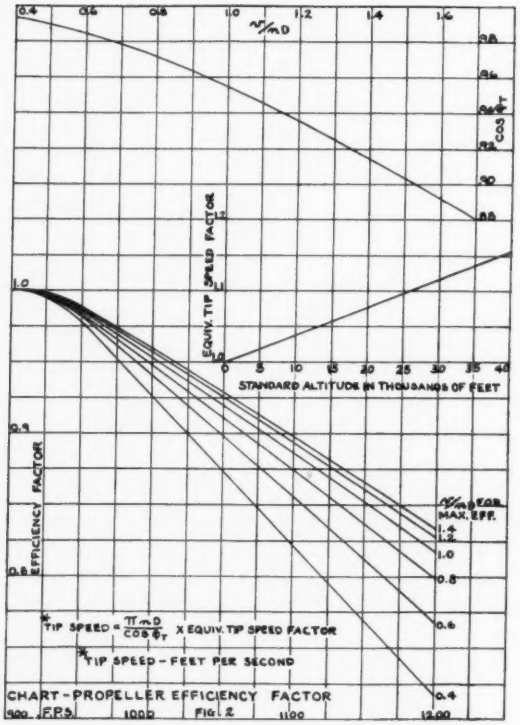
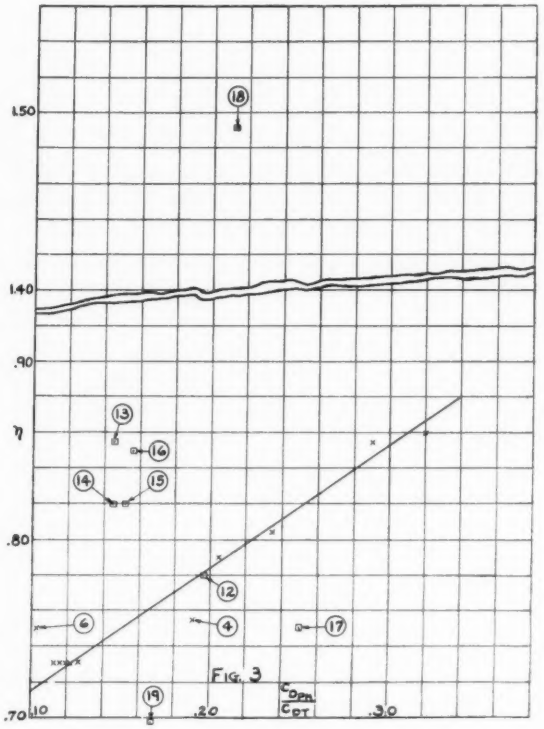

EQUIV. TIP SPEED FACTOR
STANDARD ALTITUDE IN THOUSANDS OF FEET
EFFICIENCY FACTOR
MAX. EFF.
TIP SPEED = EQUIV. TIP SPEED FACTOR
TIP SPEED - FEET PER SECOND
CHART - PROPELLER EFFICIENCY FACTOR
FIG. 2

Fig. 2 (a plot of columns 7 and 8, Table 1) shows a curve and plot of the data submitted. Note the direct variation of propulsive efficiency with the increase in percentage of nacelle drag to total. Because this type of tunnel test procedure is standard for only one tunnel, the curve is only faired through the eleven points representing tests in tunnel A. Only points (4) and (6) fall widely from the average. The efficiency for (6) was submitted as "estimated." No explanation for the variation of point (4) can be given.

The effectiveness of using "net" propeller efficiency to determine maximum velocity is measured in column 17 where the ratio of V/V_n is tabulated. This ratio was determined as follows: The net airplane drag coefficient ($C_{D_{T_n}}$) was corrected for the added drag caused by the slip stream over the wings and tail surfaces. This added drag was taken arbitrarily as 2 percent per engine nacelle (reference 3, page 154) and another 1 percent was added for each propeller blowing over the tail surfaces. Thus a twin-engined airplane has a correction factor of 1.06 and a four-engined airplane has 1.10. η_n is taken from reference 2. The cowling shapes used on the eleven airplanes considered were found, when plotted, to be close to the cowls No. 2 and No. 4 used in reference 2. These cowls give a peak net efficiency of 70 percent. The value of net efficiency of 63 percent for airplane No. 8, an amphibian with engines above the wing, was taken from reference 4. Fig. 2 gives the correction factors for tip speed for the wide, thick tipped, aluminum alloy propellers commonly used on all of the eleven airplanes. Fig. 2 varies from that on page 131, reference 3, only in the transposition of the horizontal axis. Experience has shown that the majority of propellers now used begin to suffer tip losses shortly after exceeding 900 ft. per sec. This chart is one used by the Materiel Division and gives conservative tip speed corrections for all but special design conditions.

From the flight performance equation ($D \times V/550 =$ b.hp. $\times$ η) it is easily determined that $V/V_n = \sqrt[3]{(\eta/\eta_n)} \times C_{D_{T_n}}/C_{D_T}$ for the same horsepower. This is tabulated in column 17 and shows that, but for one exception, airplane No. 6, the maximum velocity as determined by using net efficiency would check the



measured performance within ±1 percent, the accepted flight test accuracy. The average variation for eleven airplanes is only $^3/_4$ of 1 percent. The propulsive efficiency for airplane No. 6 was estimated. If it were changed to fall on the curve, Fig. 3, then its performance would also check quite accurately.

Because there are no know published propeller working charts based on net efficiencies, the complete performance of the airplane, other than level flight, will be hard to compute by this method. More data on slip stream drag on the wings and tail, especially for the climb condition, and the variation of net efficiencies with angle of attack and yaw, must be obtained before accurate computations for the phases of performance other than level flight can be made.

The ideal method of obtaining wind-tunnel data for performance estimates is to use powered models.[5,6] There is a need for special, compact, high-speed electric motors having high powers and provisions for suitable cooling. In powered model testing it is desirable to arrange the equipment so that the interaction between propeller and afterbody may be measured. From data obtained in this way, with proper equipment, all four of the propeller efficiencies, "isolated," "apparent," "net," and "propulsive," as defined by Weick, may be determined. In this way, too, the propeller slip stream drag effects may be properly evaluated. References 8 and 12 adequately describe the type of test equipment and procedure for this purpose. Fig. 4 shows a photo-

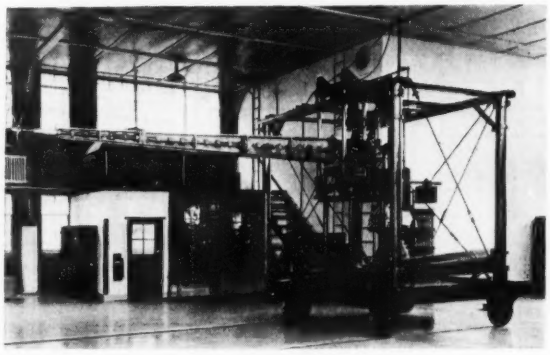


FIG. 4.

graph of a model propeller dynamometer used at the Material Division in conjunction with the five-foot wind tunnel. This type of equipment is admirably suited for the test purposes, as indicated above.

The data submitted on airplane No. 18 were recognized as inaccurate by the manufacturer. The data were obtained from a small wind tunnel, and obviously some correction factor, such as tare drag or the like, was omitted. The airplane when flown showed such performance that an adjusted propulsive efficiency of 149 percent was needed to balance the flight performance equation.

The following conclusions are drawn from the preceding paragraphs:

(1) More quantitative data concerning the effects of propeller operation on the drag of those parts of the airplane in the slip stream are needed.

(2) The drag coefficients listed for the first eleven airplanes are believed to closely represent actual full scale values. The values obtained in column 17 would tend to substantiate this belief. It is hoped that full flight and wind-tunnel investigations using thrust and torque meters can be made in the near future by those agencies concerned to obtain a check of all variables in the flight performance equation.

(3) The indicated method of using "net" efficiency for performance estimation should serve as a reliable and conservative check for level flight values now obtained in the conventional manner.

PART II

An appreciation of how effective enclosing the engines in the wing or fuselage structure may be in decreasing the drag of the airplane is obtained from inspection and study of columns 1 to 8, inclusive, of Table 1. Considering airplane No. 9, which has the highest performance of all those submitted, it is seen that the nacelle drag, including cooling, may be as high as 32 percent of the total airplane drag. This is 57 percent of the total parasite drag. For the types of airplanes involved, those with the highest percentage of nacelle drag usually have the highest performance. Thus the elimination of the nacelles in these models will provide the greatest percentage increase in performance.

Engine cooling for enclosed installations may be obtained, depending upon the individual installation, for from 5 to 10 percent of the total airplane drag. The lower limit may even be exceeded with the optimum ducted cooling arrangement. Extension shafts, whether pusher or tractor, add a negligible amount to the drag of the airplane and wing.[7] A tractor arrangement with the propellers a sufficient distance ahead of the leading edge (page 103, reference 3, and reference 12) will make a good installation if the slip stream velocity over the wing is properly evaluated. The tractor slip stream velocity has more effect than the pusher inflow velocity which may be considered negligible for the high speed condition. The pusher drag effect is small under any condition and may usually be neglected except for the effect on the tail surfaces. In the climb and approaching the stall the pusher inflow velocity will scavenge and help delay the separation on the top of the wing. Given a clean tractor extension shaft arrangement, the drag correction for slip stream velocity should not be quite as great as was used in Part I where the interference drag of the nacelle made the slip stream drag effect over the affected part of the wing much larger. Because of this negation of the nacelle interference the airplane will have an improved maximum L/D, due both to decreased drag and to increased lift; the latter, because

local separation formerly induced by the nacelle interference is avoided. The increased L/D will substantially improve the range of a given airplane. The increased maximum lift will appreciably lower the landing speed. In addition to the greatly decreased drag with nacelles removed, an increased propeller efficiency will still further increase the maximum velocity.

The propeller efficiencies that may be used are the so-called "isolated" efficiencies obtained by mounting the propeller in the wind tunnel on a long cantilever arm free from body effects. These efficiencies will be several percent higher than the net efficiencies reported in reference 2, because there is no nacelle body drag to be overcome. The propeller working charts and characteristics plotted in Figs. 5 to 10, inclusive, have not been generally published before. They are from wind-tunnel tests made for the U.S. Army Air Corps at Stanford University in 1929 on a series of five three-blade propellers with uniform pitch distributions varying from $P/D = .314$ for propeller SK5676 to $P/D = 1.57$ for propeller SK5680. These data are believed to be the most modern available with uniform pitch distributions, tested so as to give "isolated" propeller efficiencies. With either tractor or pusher extension shaft drives, data on propellers with uniform pitch distributions are needed because there are no afterbodies to affect the local angle of attack along the blade. A varying pitch distribution is now common practice with radial-engined installations. Reference 8 describes test equipment similar to that used for the propeller tests just described. This reference also explains the necessity for varying pitch distribution for propellers operated in front of engine nacelles. Of interest is Fig. 6 for propeller SK5676. This is the identical propeller in every respect as regards thickness, width, planform, and pitch distribution, to that tested on the powered model of reference 5. Note the increase values of "propulsive" efficiency from the GALCIT tests over the "isolated" efficiency from the Stanford test. The nacelle and fuselage body aft of the propeller in the former tests slowed down the air through the propeller disc moving the entire efficiency envelope to the right. The engine cowl on the GALCIT test obviously had poor drag characteristics because the "propulsive" efficiencies, which are for the whole airplane model, are appreciably higher than those for the propeller alone.

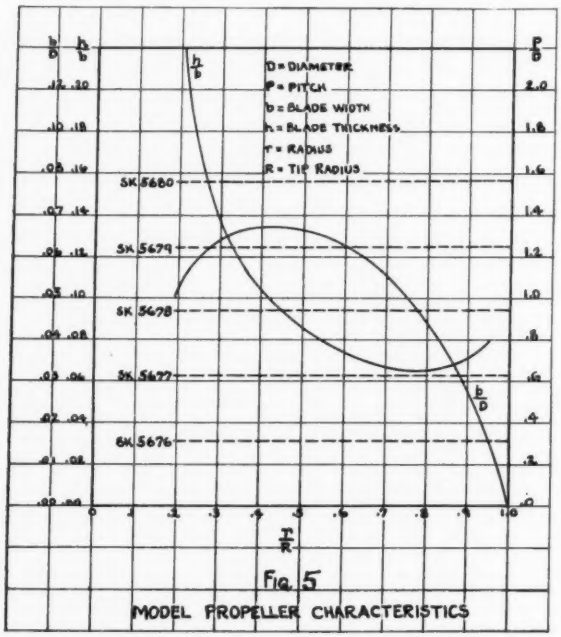


Fig. 5

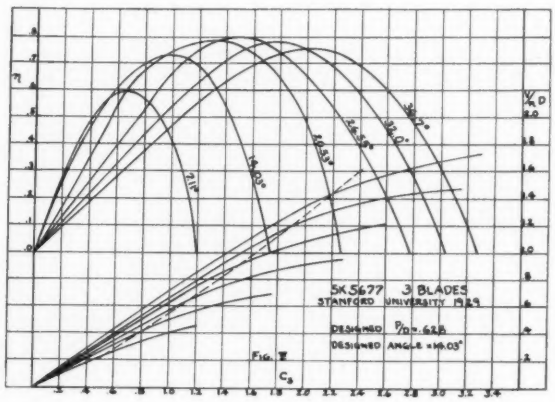


Fig. 7

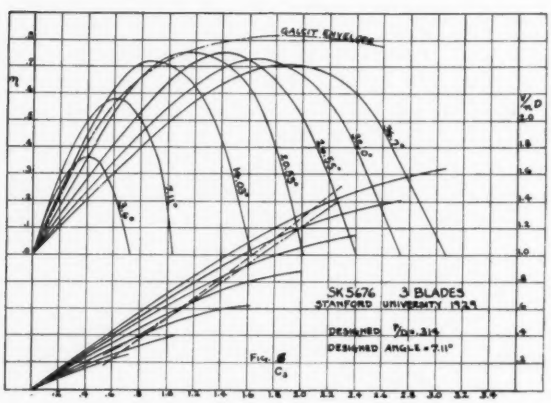


Fig. 6

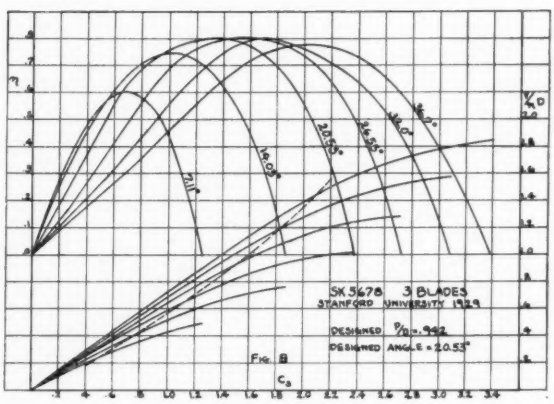


Fig. 8

Whenever this situation occurs it usually means that the propeller slip stream has greatly reduced the drag of the body in its wake from those values determined with the propeller removed. It is this "effective thrust" action which makes the use of "propulsive efficiency" so misleading to those unfamiliar with its true significance and proper application.

The criticism may be advanced that these model propeller tests do not accurately represent full scale propeller characteristics. It is believed, however, that the efficiencies and other values plotted may be used without correction except for tip speed effects as determined from Fig. 2. The gain in performance due to increase in scale is about balanced by the higher drags of the thicker full scale sections commonly used on propellers today. The values as presented have been checked against all available large scale data and are believed accurate in their present form.

It is suggested that the following method may be quite accurately and conservatively used in predicting the performance of airplanes with enclosed engines and extension shaft drives, given good wind-tunnel data or data which can be extrapolated and corrected to give representative full scale drag values. The wind-tunnel data without operating propellers are taken and the ordinary procedure is used in calculating the various phases of performance using the "isolated" propeller values corrected for tip speed as herein presented. Corrections to the drag values for propeller slip stream must be made as required for the individual installation. Corrections to propeller efficiency for pitch and yaw in the climb conditions must be made as indicated in references 7, 9, 10, 11.

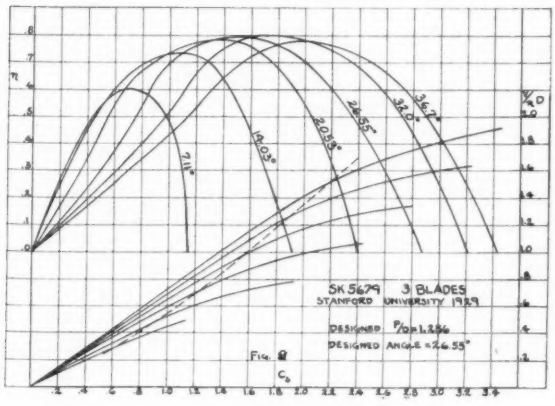
Few tests of airplanes and models of the type described are available and performances calculated by the above method have not been compared with full flight results. It is concluded, however, that enclosing the engines in the structure of the wing or fuselage of an airplane and driving the propellers through extension shaft drives promises to provide a considerable improvement in aerodynamic efficiency.

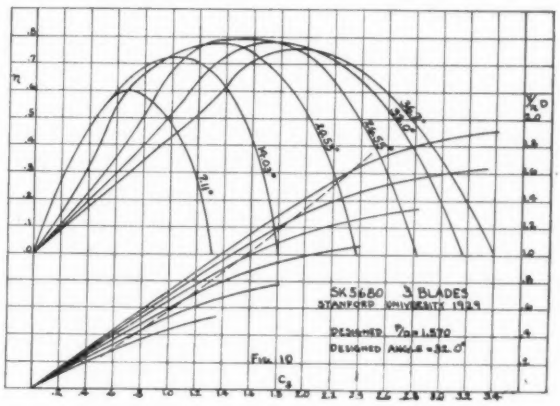
Part III

Short discussions of a few propeller problems of immediate interest are given below.

(a) The relatively heavy tipped propellers commonly used to date have been found to require tip speed corrections as presented in Fig. 2. Lately, however, a few performance tests of high-speed airplanes at fairly high altitudes, with excessive propeller tip speeds and using "flash" power and r.p.m. ratings, have not shown quite the tip losses that are experienced at the lower altitudes at normal power and r.p.m. ratings and slower forward velocities. There are a considerable number of recent N.A.C.A. technical reports dealing with the compressibility losses at velocities approaching that of sound. Reference 13 discusses the compressibility burble phenomenon and its application to the propeller problem. To avoid high drag on airfoil sections moving close to the velocity of sound, it is necessary to keep the local velocity increase and its associated change in pressure, as measured by the ratio $(P - P_0)/{}^1/_2\rho_0 V_0^2$, a minimum. Thin sections of minimum mean camber ratio are required, working close to their maximum L/D, which for propeller sections will normally be between 0° and 1° angle of attack. To avoid prohibitive losses at overspeed ratings where the tip velocities exceed .90c, it must be stressed that all sections along the propeller blade must be working at their optimum conditions and that the critical unfaired shank portions of the blades must be protected by a spinner or blade fairings. (See Fig. 21, reference 13.)

(b) The present metal propeller blade planforms have developed through the experience of many years to those shapes commonly used today because of the necessity of avoiding rapid changes in cross-section and their associated stress concentrations in the heavily stressed shank portions of the blade. Airplane performances are rapidly approaching those values wherein the drag of these poorly faired shank portions, when exposed to the full airplane velocity, are beginning to assume excessive proportions. Preliminary calculations, which have yet to be checked by flight performance, would tend to show that a propeller with a proper spinner





and blade shank fairings as compared to a conventional propeller, when installed on a sharp-nosed nacelle or extension shaft, should increase the power available at speeds between 350 and 400 m.p.h. by a conservatively estimated 10 to 15 percent. The attachment of these fairings to the blades or hub of a controllable propeller so as to permit their rotation with the blades and still withstand the high stresses imposed by centrifugal and vibratory forces presents a difficult engineering problem. These blade fairings, so-called "cuffs," should also aid in cooling radial engines and perhaps provide a slight increase in propeller efficiency, or, more properly, the power available.

Appendix

Definitions of the four propeller efficiencies referred to in this paper are given below. They are taken from Weick, pages 140 and 141, reference 3, and paraphrased where necessary.

The "isolated" efficiency, $TV/2\pi nQ$, is that for the propeller alone as tested on a long extension shaft in free air.

The "apparent" efficiency, $TV/2\pi nQ$, is that obtained by measuring the thrust and torque absorbed by the propeller in the presence of a body, but no evaluation is made of the effect of the slip stream on the drag of the body.

The "net" efficiency, $V(T - R)/2\pi nQ$, is that obtained by using "net thrust" where the combination of propeller and body is looked upon as a complete propulsive unit. The "net thrust" is considered the resultant horizontal force and equals the propeller thrust minus the body drag, each measured in the presence of the other.

The "propulsive" efficiency, $V\,[T - (R - R_0)]/2\pi nQ$, is that obtained by using "effective thrust." R_0 is the drag of the body without a propeller. The thrust effective for propulsion is therefore the actual propeller thrust T in the presence of the body minus the increase in body drag, or $(R - R_0)$, which is caused by the propeller. $(R - R_0)$ usually has a negative value for cowled, radial-engined nacelles and represents a decrease in body drag because of the propeller slip stream.

References

[1] Weick, Fred E., *Working Charts for the Selection of Aluminum Alloy Propellers of a Standard Form to Operate with Various Aircraft Engines and Bodies*, N.A.C.A. Technical Report No. 350, 1930.

[2] Theodorsen, Theodore, Stickle, George W., and Brevoort, M. J., *Characteristics of Six Propellers Including the High Speed Range*, N.A.C.A. Tech. Report No. 594, 1937.

[3] Weick, Fred E., *Aircraft Propeller Design*, McGraw-Hill, 1930.

[4] Wood, Donald H., *Tests of Nacelle-Propeller Combinations in Various Positions with Reference to Wings. Part 1. Thick Wing—N.A.C.A. Cowled Nacelle—Tractor Propeller*, N.A.C.A. Technical Report No. 415, 1932.

[5] Russell, J. S., and McCoy, H. M., *Wind-Tunnel Tests on a High Wing Monoplane with Running Propeller*, Journal of the Aeronautical Sciences, Vol. 3, January, 1936.

[6] Boname, Robert, *The Construction and Use of a Commercial Wind Tunnel*, L'Aéronautique, pages 165–173, August, 1936.

[7] Wood, Donald H., and Bioletti, Carlton, *Tests of Nacelle-Propeller Combinations in Various Positions with Reference to Wings. VI—Wings and Nacelles with Pusher Propellers*, N.A.C.A. Technical Report No. 507, 1934.

[8] Lesley, E. P., and Reid, E. G., *Tests of Five Metal Model Propellers with Various Pitch Distributions in a Free Wind Stream and in Combination with a Model VE-7 Fuselage*, N.A.C.A. Technical Report No. 326, 1929.

[9] Freeman, Hugh B., *The Effect of Small Angles of Yaw and Pitch on the Characteristics of Airplane Propellers*, N.A.C.A. Technical Report No. 389, 1931.

[10] Windler, Ray, *Tests of a Wing-Nacelle-Propeller Combination at Several Pitch Settings Up to 42°*, N.A.C.A. Technical Report No. 564, 1936.

[11] Lesley, E. P., Worley, Geo. F., and Moy, Stanley, *Air Propellers in Yaw*, N.A.C.A. Technical Report No. 597, 1937.

[12] Durand, W. F., *Interaction Between Air Propellers and Airplane Structures*, N.A.C.A. Technical Report, No. 235, 1926.

[13] Lock, C. N. H., *Problems of High Speed Flight as Affected by Compressibility*, Royal Aero. Soc., Journal, March, 1938.

Book Review

Count Zeppelin, by Dr. Hugo Eckener; translated by Leigh Farnell; Massie Publishing Co., Ltd., London, 1938; 275 pages, 8s. 6d.

The exceptional character of this biography lies not only in the subject, Count Zeppelin, one of the most remarkable men in aeronautical history, but also in the fact that it is written by Dr. Hugo Eckener, the man who carried on the work of the development of dirigibles since Zeppelin's death in 1917.

The purpose of the book is to give German readers a better understanding of the events in Count Zeppelin's life before he became interested in airships. He served the King of Wurtemberg as an army officer until he was fifty-two years old. Dr. Eckener quotes freely from the diary kept by the Count during all these years. These comments on his activities mirror the strong traits of honor, persistence, and loyalty that were responsible for so much of Count Zeppelin's success. Of particular interest to the American reader is the account of the experiences and impressions of Lt. Zeppelin's visit to the United States during the Civil War when he had exceptional opportunities to observe the functioning of the Northern Army. His comments, though not flattering, are those of an impartial observer.

The latter part of the book gives an intimate view of his early work on the rigid type of airship. He recounts the obstacles that had to be overcome in arousing interest in this new type of aircraft. Mishaps, discouragements, and tragic accidents failed to quench the spirit of the determined inventor.

Though Count Zeppelin at last gained public confidence and support, the technical shortcomings of the early Zeppelins left Dr. Eckener with great problems still to be overcome. It would be interesting to have another biographical book by Dr. Eckener on the progress and development of the airship since he has been the leader in this field. Two such books, covering the work of two great pioneers, would give the world a comprehensive picture of airship development.

The Use of Symmetric and Anti-Symmetric Loadings

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REGARDLESS of the skill which a stress analyst may have in adapting one of the general methods of analysis to a given problem, the evaluation of the loads occurring in the members of a statically indeterminate structure is a tedious process. In certain cases, such as a symmetrically loaded symmetrical structure, advantage may obviously be taken of special arrangements of loads, members, pinned joints, or similar features, and equations of condition may be established which, when used in conjunction with the equations of statics and the principle of consistent deformations, yield solutions with the minimum of trouble to the designer. The advantages of symmetry may be had on any symmetrical structure, whether or not the load be symmetrical, by deliberately substituting two or more equivalent force systems for the original loading. It is the purpose of this paper to show how the equivalent systems should be disposed.

The fundamentals of the procedure for arranging the forces appear to have originated in Germany[1] about twenty years ago, but their application does not seem to be widely known in the United States. In the case of the usual symmetrical structure two loading systems replace the one for which the structure is actually to be designed. One system has all forces and reactions symmetrically disposed about the plane of symmetry of the structure, the second has them arranged anti-symmetrically. In the latter system, forces which have components acting toward the plane of symmetry of the structure on one side of that plane have counterparts acting away from that plane on the other side of it; forces having components acting upward on one side have counter-parts acting downward on the other, and so on. Anti-symmetrical moments tend to produce compression in the upper fiber at a section on one side of the plane of structural symmetry, tension in the upper fiber of a corresponding section on the other side.

Under such loadings there exist relations involving not only forces and moments but also slopes and deflections, hence it becomes possible to establish twelve general equations of condition which are compatible with the principle of consistent deformations, and statics, and which are useful in the analysis of any symmetrical, statically indeterminate structure. These conditions are:

A. For a structure having loads symmetrically disposed about a plane of structural symmetry:

I. The force components acting on and parallel to the plane—those producing shear on a section through the plane of symmetry—are zero.

II. The slope of the tangent to the elastic curve at the plane of symmetry is independent of the magnitude of the applied loads on the structure.

III. The component of the deflection normal to and at the plane of symmetry is zero.

B. For a structure having loads symmetrically disposed about a plane of structural symmetry the reactions must comply with the following conditions:

IV. Components parallel with the plane of symmetry must be equal in magnitude and act in the same direction.

V. Components normal to the plane of symmetry must be equal in magnitude, but act in opposite directions.

VI. Moments serving to fix the slope of the structure at the supports must be equal in magnitude, but of the opposite hand.

C. For a structure having loads anti-symmetrically disposed about a plane of structural symmetry:

VII. The components of forces acting perpendicular to a section through the plane of anti-symmetry are zero. (This is the only condition compatible with the existence of compression on one side of that plane, tension on the other.)

VIII. The magnitude of the bending moment acting on the plane of anti-symmetry is zero.

IX. That component of the deflection of the plane of anti-symmetry which is parallel to the plane must be zero when measured with respect to a line joining the ends of the structural element in which the plane of anti-symmetry lies.

D. For a structure having loads anti-symmetrically disposed about a plane of structural symmetry the reactions must comply with the following conditions:

X. Components parallel to the plane of anti-symmetry must be equal in magnitude, but must act in opposite directions.

XI. Components perpendicular to the plane of anti-symmetry must be of the same magnitude, and must act in the same direction.

XII. Moments tending to fix the slope of the structure at the points of support must be equal in magnitude and act in the same direction.

As an illustration of the utility of the substitute load systems and their equations of condition, consider the framed-bent shown in Fig. 1a. The supports at a and e are "built-in," the structure is indeterminate to the third degree, and with the load applied as it is to produce bending and direct stress in each element of the structure a solution obtained by least work, although straightforward enough in principle, is somewhat burdensome as to algebra. Insofar as the principle of superposition applies to them, it is obvious that a summation of the stresses produced in the various members by the loads on the structures of Fig. 1b and 1c will be equal to those arising from the original load in Fig. 1a, hence, that the stresses to be used in design will not be affected by use of the substitute loadings. By isolating the left half of the structure in Fig. 1b and indicating the forces acting upon it, the system of loads and members shown in Fig. 2a is obtained.

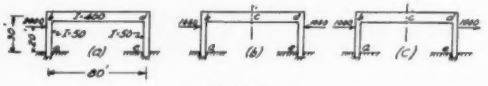

FIG. 1.

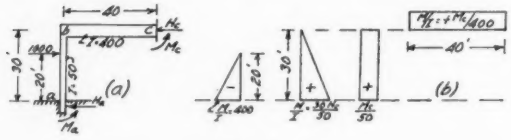

FIG. 2.

By Condition I, $V_e = 0$, hence V_a must be zero in order that $\Sigma V = 0$ on the isolated portion of the bent. There is no change in slope at c due to the application of the load, by Condition II, and none at a because the support is built-in to prevent it. Since the change in slope between the tangents to the elastic curves at a and c is zero, the sum of the areas under the M/I curves between a and c must, by the moment-area theorems, also be zero. Considering the M/I curves of Fig. 2b, and designating as positive those moments which tend to make the point c deflect upward,

$$30\left(\frac{30\,H_c}{50 \times 2} + \frac{M_c}{50}\right) + \frac{40\,M_c}{400} - \frac{20 \times 400}{2} = 0 \quad (1)$$

By Condition III, the horizontal component of the deflection of point c with respect to the tangent to the elastic curve at a is zero, hence,

$$\left(\frac{30 \times 30H_c}{50 \times 2}\right)\left(\frac{2}{3} \times 30\right) + \frac{30M_c}{50}\frac{30}{2} - \left(\frac{20 \times 400}{2}\right) \times \left(10 + \frac{2}{3}20\right) = 0 \quad (2)$$

From Eqs. (1) and (2), $M_c = -2667$ and $H_c = 650$.

Isolating the left half of the bent of Fig. 1c, that subjected to the anti-symmetrical loads, and indicating the forces and moments acting upon it, the structure of Fig. 3a results. M_c and H_c are zero by Conditions VII and VIII, while the deflection of point c from a line through b and d is zero by Condition IX. The latter relation suffices for the determination of V_c since the slope at b is

$$E\theta_b = (-400 \times 20/2) + (30 \times 40V_c/50)$$

Were there no bending in the girder bd, point c would be $40E\theta_b$ below the line bd. In order that c shall not deflect below bd the deflection of c from the tangent to the elastic curve at b must be $-40E\theta_b$, hence,

$$\left(\frac{-400 \times 20}{2} + \frac{30 \times 40V_c}{50}\right)40 + \left(\frac{40\,V_c}{400} \times \frac{40}{2} \times \frac{2 \times 40}{3}\right) = 0 \quad (3)$$

V_c as found from Eq. (3) is 158.

By the equations of statics, $H_a = 1000$, $V_a = 158$, and $M_a = 13{,}680$ for the anti-symmetrical load. For the original bent and loading, $V_a = 158$, $H_a = 1350$, and $M_a = 16{,}850$, acting as shown in Figs. 2a and 3a. With these quantities known, the reactions at the right support, or the shears, moments, and normal forces at any other section, are readily determined by statics.

The comparative merits of the methods of using the original loading and the substitute loads may well be shown by solving the above structure for both systems by the method of least work.

An example more immediately applicable to airplane design is that of a circular ring subjected to a single concentrated load, $2P$, and a circumferential shear stress distributed according to the elementary theories of bending and torsion, as shown in Fig. 4. Such a system of forces may represent a seat load or floor load on the transverse stiffening ring of a circular fuselage, the shear stresses being those developed in the covering to which the ring is attached. If the covering is stiffened by longitudinal members, as would be the case in the normal fuselage, that part of the circumferential stress which is equal to the longitudinal shear, VQ/tI, would not vary as a continuous function but would have a saw-tooth variation for which the distribution indicated in Fig. 4a may be taken as an average, the area of the stiffeners being treated as though distributed around the circumference in the form of an increased thickness of covering.

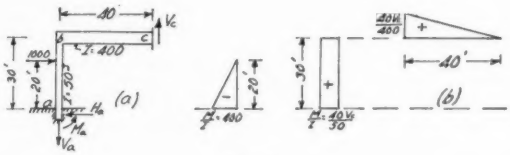

FIG. 3.

By taking the planes of symmetry and anti-symmetry at right angles to the load $2P$, the systems of symmetric and anti-symmetric forces equivalent to the original loading are shown in Fig. 4b and 4c. Cutting the ring

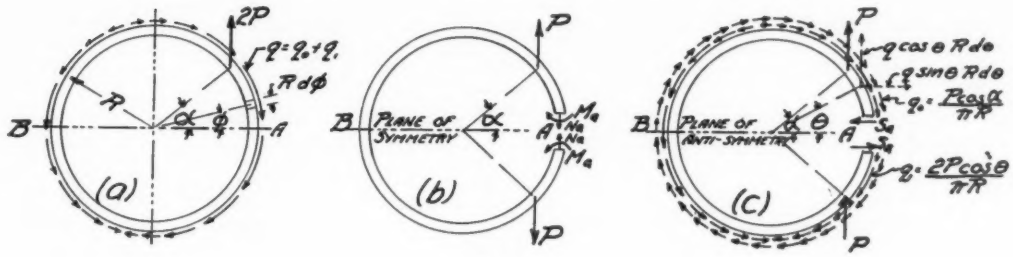

FIG. 4.

of Fig. 4b through the plane of symmetry at A, it is evident that there are but two unknowns, the normal force N_a and the moment M_a, since, by Condition I, the shear force on the section is zero. Further, the slopes of the tangents to the elastic curves at A and B do not change as the load P varies—Condition II—and that the tangential components of the deflection of points A and B are zero by Condition III. If change in slope of a curved beam were equal to the area under the M/EI curve, as the moment-area method shows it to be for a straight member, it would be possible to proceed as in the case of the framed bent above and use the moment-area relations for slopes and deflections. But, since the segment AB is curved, the relation[2] between M/EI and deflection becomes $M/EI = -(u/R^2) - d^2u/ds^2$, where u is the radial component of the deflection on a circle of radius R. The simple relation between M/EI and the second derivative of the deflection, taken with respect to the length of the member, which holds for straight beams is complicated by the additional term involving the ratio of the radial displacement and the radius squared, and it looks as though any attempt to proceed by the use of moment-area relations would be somewhat tedious.

Because of the symmetry of structure and loading, however, the following conditions exist:

At $\varphi = 0$, the slope, $du/d\varphi = 0$; at $\varphi = \pi$, $du/d\varphi = 0$. Furthermore, at the same points, the tangential component of the displacement, v equals zero as was noted above, and $dv/d\varphi = -u$, hence,

$$v_\pi - v_0 = -\int_0^\pi u d\varphi = 0$$

By rewriting the relation between M and the deflection, with $Rd\varphi$ replacing ds, the expression to be integrated with respect to φ between the limits 0 and π becomes,

$$\int^\pi u d\varphi = -\int_0^\pi \frac{d^2u}{d\varphi^2} d\varphi - R^2 \int_0^\pi \frac{M d\varphi}{EI} = 0$$

$$= (du/d\varphi)_\pi - (du/d\varphi)_0 - R^2 \int_0^\pi \frac{M d\varphi}{EI} = 0$$

Hence, between the limits in which we are interested,

$$\int_0^\pi (M/EI) d\varphi = 0, \quad \text{or} \int_0^\pi (M/EI) ds = 0 \quad (4)$$

Either form of Eq. (4) may be used to establish an independent equation for use in obtaining a solution. It is interesting to note that the second one is similar to the expression for change in slope obtained from the moment-area relations on a straight beam, but that it only holds in the case of a circular beam when the sections between which it is desired to obtain the difference in slope are at $\varphi = 0$ and $\varphi = \pi$, and then only under symmetrical conditions of load.

By recourse to a simple mathematical strategem it may be shown that

$$\int_0^\pi (M \cos \varphi / EI) d\varphi = 0$$

The procedure is to integrate by parts

$$\int_0^\pi (d^2u/d\varphi^2) \cos \varphi \, d\varphi = \cos \varphi \, (du/d\varphi) \Big|_0^\pi +$$

$$\int_0^\pi (du/d\varphi) \sin \varphi \, d\varphi = 0 + (\sin \varphi) u \Big|_0^\pi - \int_0^\pi u \cos \varphi \, d\varphi$$

which yields

$$\int_0^\pi \left(u + \frac{d^2u}{d\varphi^2}\right) \cos \varphi \, d\varphi = -R^2 \int_0^\pi \frac{M \cos \varphi \, d\varphi}{EI} = 0$$

And, since R is a constant,

$$\int_0^\pi \frac{M \cos \varphi \, d\varphi}{EI} = 0, \text{ or } \int_0^\pi \frac{MR \cos \varphi \, ds}{EI} = 0 \quad (5)$$

Either form of Eq. (5) may be used in a given problem, but it is to be noted that the second form is again a moment-area relation for the tangential component of the deflection at B taken with respect to the tangent to the elastic curve at A. For the loading condition assumed, the expression is exact; but for other loadings or other limiting values for φ, the moment-area relations are not valid. The degree of approximation in their use will depend on the magnitude of the u/R^2 term as compared with the second derivative term, and they should not be used when the radial displacement is appreciable, or when the radius of the member is small.

Eqs. (4) and (5) are sufficient for the determination of the two unknowns, M_a and N_a, once the moment at any section has been established in terms of these and the known quantities. From Fig. 4b it is readily seen that for values of φ less than α,

$$M_1 = M_a + N_a (R - x) = M_a + N_a R (1 - \cos \varphi) \quad (6)$$

while for values of φ between α and π

$$M_2 = M_1 - PR(\cos\alpha - \cos\varphi) \quad (7)$$

If, for the purposes of this problem, EI be assumed constant, Eqs. (4) and (5), written in terms of Eqs. (6) and (7), become,

$$\int_0^\pi M\,d\varphi = 0 = \int_0^\alpha M_1\,d\varphi - \int_\alpha^\pi PR(\cos\alpha - \cos\varphi)\,d\varphi$$

$$\int_0^\pi M\cos\varphi\,d\varphi = \int_0^\alpha M_1\cos\varphi\,d\varphi - \int_\alpha^\pi PR(\cos\alpha - \cos\varphi)\cos\varphi\,d\varphi$$

Expressing M_1 in terms of M_a and N_a, performing the indicated integrations, and simplifying these equations gives,

$$M_a = (PR/\pi)(\cos\alpha - 1)(\pi - \alpha - \sin\alpha) \quad (8)$$

$$N_a = (P/\pi)(\pi - \alpha + \sin\alpha\cos\alpha) \quad (9)$$

Eqs. (8) and (9) suffice for the determination of the unknowns in the case of the symmetrically loaded structure.

For the anti-symmetrically loaded structure shown in Fig. 4c the concentrated loads, P, produce twisting and shearing of the shell for which the ring acts as transverse stiffener. The twisting is offset by a torsional force q_0 pounds per inch of circumference, while the shear is resisted by a varying tangential force, q_1, which is a function of the longitudinal shear stress developed in the shell. Assuming the thickness of the shell to be constant,

$$2PR\cos\alpha = 2\pi Rq_0R$$

$$q_0 = P\cos\alpha/\pi R \quad (10)$$

The longitudinal shear stress on a section making an angle θ with the axis is,

$$f_s = VQ/tI = 2PR^2t\cos\theta/t\pi tR^3$$

and if it is assumed that this is the average stress on a one inch strip whose center makes an angle θ with the axis, the force on that strip is

$$q_1 = f_s t = 2P\cos\theta/\pi R \quad (11)$$

Then the total shear force, q, is $q_0 + q_1$ pounds per inch where,

$$q = (P/\pi R)(\cos\alpha + 2\cos\theta) \quad (12)$$

Since the section is loaded anti-symmetrically, the moments and normal forces at A and B of Fig. 4c are zero by Conditions VII and VIII, while the radial displacements, u, at those points are zero by Condition IX. The shear force, S_a, is the only unknown on the section cut by the plane of anti-symmetry shown in Fig. 4c, and it may be evaluated by using Castigliano's theorem, since the deflection u_a in the direction of S_a is zero, or it may be determined by use of an expression similar to that employed for the symmetrical load. Integration of $\int_0^\pi u\sin\varphi\,d\varphi$, with due regard for the facts that $u = 0$ at $\varphi = 0$, and that $d^2u/d\varphi^2 = 0$ at the same points, gives

$$\int_0^\pi (M\sin\varphi/EI)d\varphi = 0, \text{ or } \int_0^\pi (MR\sin\varphi/EI)ds = 0 \quad (13)$$

As in the case of the second form of Eq. (5), the second form of Eq. (13) expresses the moment-area relation for the radial component of the deflection at B taken with respect to the tangent to the elastic curve at A. Either form of Eq. (13) suffices for the determination of the unknown shear at A, since the expressions for the moment M involve but the one unknown. For values of φ between zero and α,

$$M_1 = S_aR\sin\varphi + R^2\int_0^\pi q[1 - \cos(\theta - \varphi)]d\theta \quad (14)$$

while for values of φ between α and π,

$$M_2 = M_1 - PR(\cos\alpha - \cos\varphi) \quad (15)$$

Substituting Eqs. (14) and (15) in Eq. (13), with due regard for the limits, carrying through the integrations and simplifying the resulting equations,

$$S_a = (P/\pi)[\cos\alpha(1 + \cos\alpha) - \tfrac{1}{2}] \quad (16)$$

Eqs. (8), (9), and (16) suffice for the determination of the moment, normal force, and shear at A on a circular ring having constant EI and carrying a force of magnitude $2P$ acting perpendicular to the plane of the section at A. If there be more than one force acting on the ring, the values of M_a, N_a, and S_a may be computed for each load and the results added to obtain the total moment, normal force, or shear at the section A.

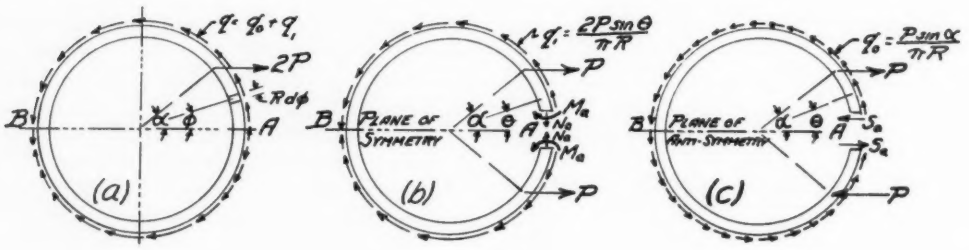

FIG. 5.

If the force $2P$ acts parallel with the planes of symmetry and anti-symmetry, instead of perpendicular as in the case just considered, the tangential shear stress corresponding to q_1 of Eq. 11 becomes $2P \sin \theta/\pi R$ and it is symmetrically disposed, while the shear due to torsion, that corresponding with q_o of Eq. (10), becomes $P \sin \alpha/\pi R$. It is anti-symmetrically disposed as shown in Fig. 5.

The expressions for moment, normal force, and shear at section A of a ring of constant EI, loaded as shown in Fig. 5, are

$$M_a = (PR/\pi)[1/2 + \cos \alpha - (\pi - \alpha) \sin \pi + \sin^2 \alpha] \quad (17)$$

$$N_a = (P/\pi)[3/2 - \sin^2 \alpha] \quad (18)$$

$$S_a = (P/\pi)[(\pi - \alpha) - \sin \alpha - 1/2 \sin 2\alpha] \quad (19)$$

Eqs. (8), (9), (16), (17), (18), and (19) make it possible to determine the moment, normal force, and shear on one section of a circular ring whether the concentrated load be parallel with or perpendicular to the plane of the section. By resolving a load acting at any intermediate angle into components which are parallel and perpendicular, the moments, shears, and normal forces on a given section may be determined for any system of concentrated loads, and once these quantities have been obtained for one section they may be computed for any other section of the ring by simple statics.

The final equations derived above are for a ring having a constant EI, and for one which is supported by forces around its circumference such as those developed by the covering on a fuselage for which the ring acts as a transverse stiffener. They are of considerable use in the analysis of such members, and by developing tables of the coefficients for PR/π and P/π in terms of α, the labor of using them could be materially reduced. The construction of such tables is contemplated.

Whether or not it is desirable to develop similar general expressions for uniformly distributed radial loads, for elliptical sections, or other shapes is a question. It is believed that such expressions may be obtained more readily by the use of systems of symmetric and anti-symmetric loads than by dealing with the applied loads directly.

References

[1] Andrée, W. L., *Das B = U Verfahren;* R. Oldenbourg, München and Berlin, 1919; Kaufman, W., *Statik der Tragwerke;* Springer, Berlin, 1930, Second Ed., page 190; and Bleich, F., *Berechnung statisch unbestimmter Tragwerke;* Springer, Berlin, 1925, Second Ed., page 155.

[2] Timoshenko, S., *Strength of Materials,* Vol. II, page 459, Eq. (53), D. Van Nostrand Company, Inc., New York, 1930; or J. Prescott, *Applied Elasticity,* page 288, Eq. (11.78), Longmans, Green and Company, New York, 1924.

Book Reviews

The Clouds Remember, by Leonard Bridgman, commentary by Oliver Stewart; Gale and Polden, Ltd., Wellington; 128 pages, 10s. 6d.

Leonard Bridgman has for many years been known for his excellent drawings of aircraft. In this book he presents a series of sketches of the more famous European airplanes which have made aeronautical history. Accompanying each picture is a commentary by Major Oliver Stewart, the aeronautical correspondent of the Morning Post of London and a British pilot of long experience.

The combination could not be bettered. The memories evoked by the pictures and the descriptions by Major Stewart are more like stories of old friends than of mechanical devices. He differentiates each type of plane by telling of its accomplishments and something of the pilots who became famous flying them. Forty different types are discussed and when the American reader has finished reading of the French and English designs, he wishes that similar expert commentators here would write a book on the early American airplanes. In fact, it would be equally interesting if the English authors would provide a second volume on later English aircraft so that we could have not only what "the clouds remember," but impressions of the more modern British developments as well.

The book has a wealth of information on the use of aircraft during the war. It introduces each successive type with comments that place it in its proper position in the wartime effort. The almost affectionate regard that Major Stewart has for many of the better known machines is evident.

For those who wish to renew their friendship with their favorite wartime aircraft, no book could be more acceptable. For those who did not reach the Front, the book gives a well rounded idea of the vicissitudes of the pilots in their attempts to carry out their missions with the aircraft then available.

The Air Defense of Great Britain, by Air-Commodore L. E. O. Charlton, G. T. Garratt, and Lieut.-Commdr. R. Fletcher, M.P.; Penguin Books, Ltd., Harmondsworth, England, 1938; 224 pages.

This booklet is one of a series on present-day problems in Europe. It contains three studies of the air defense problem in England. Air-Commodore L. E. O. Charlton in the first section "The New Factor in Warfare" covers ground that is familiar to those who have read his recent books. He is one of the leading English proponents of the ultimate supremacy of air power in warfare and has been crusading many years for adequate air defense. The second part, on "Air Raid Precautions" by G. T. Garratt, is a very general summary of the problems that arise in the event of bombing raids. The third part, on "Britain's Air Strength" by Lieut.-Commdr. R. Fletcher, M.P., reads like a Congressional investigation of the British aircraft industry. He discusses the financial and production situation of the industry and in a scathing attack gives much interesting information on, as well as criticism of, the British aircraft program. He discusses the Shadow Factories and the relations of labor in the industry. He claims that there has been "incompetence, waste, inefficiency, and muddle" and places the blame on the Air Ministry. These chapters give the impression of a speech of the "opposition" in Parliament but they do make interesting reading.

Correlation of Aircraft and Ground Station Altimeters

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Presented at the Instruments Session, Seventh Annual Meeting, I. Ae. S.
January 25, 1939

CLOSE correlation of ground station and aircraft altimeter equipment on a transcontinental airline is a difficult task. A great number of units are involved because of the large number of airplanes operated over such a route, and each aircraft is equipped with two sensitive altimeters. In addition, each station is provided with another altimeter which is set up to be used as a means for correcting the aircraft altimeters during flight. This task is further complicated by operation from fields which vary in temperature and elevation by considerable amounts. For instance, on a single transcontinental trip, an airplane will make landings at fields whose elevations range from sea level to over 6000 ft. Also, during the course of this flight, it is quite possible for the ground temperatures to vary by 80°F. or more.

The sensitive altimeters now employed for determining and controlling aircraft altitudes are very precise mechanisms. Many improvements have been made during the past several years so that these instruments are many times more sensitive and accurate than the barometric pressure units first employed as altimeters in aircraft.

The problem of correlating the readings of all the sensitive altimeters now required by an airline is a most difficult one. It is the purpose of this paper to point out some of the many factors which are involved in correlating the readings and, further, to describe some of the steps which have been taken to keep the overall errors to a minimum.

While no one single error or variation is likely to be very great, it is the possible combination of a great number of these variables which renders the task so difficult. Following is a list of some of these different factors. The only items treated in detail are those over which the airlines have some measure of control.

Variations may, in general, be placed under the following five classifications:

(A) Errors in the basic standard instrument (normally a mercurial barometer).

(B) Inability of the indicating instruments themselves to be calibrated to conform to the exact standard altitude pressure tables and to be free from errors of temperature, friction, balance, etc.

(C) Personnel errors. These involve the instrument technicians, the dispatchers, and the flight crew.

(D) Errors or variations inherent in the installation of the indicating equipment, both in the aircraft and in the dispatch office.

(E) Miscellaneous corrections which must be applied, such as those necessary to compensate for incorrect or non-uniform field elevations.

Basic Standard Instrument Deficiencies

First of all, it is necessary for an airline operator to select and use only one mercurial barometer as the basic standard for his system in order to eliminate discrepancies which would result if he attempted to utilize more than one such instrument for controlling the setting of his indicating equipment. This mercurial barometer will usually be located in the instrument repair shop.

Ultimately it is hoped that, through efforts now under way, it will be possible for each of the airline operators to coordinate their mercurial barometers more closely than has been possible in the past. It is believed that whenever this coordination is attempted, it cannot help but involve considerable confusion for a time. However, it is recognized that eventually such a coordination must be effected if maximum benefits are to accrue.

A readability and a sensitivity equal to or better than that of the sensitive altimeter should be available in the mercurial barometer. In the past this has not been the case, but some of the improvements in mercurial barometers now contemplated may result in a basic standard much better adapted to airline needs. At the present time, successful use of the mercurial barometer can only be obtained through careful control of temperatures, careful adjustment of the scale, and the restriction of its use to a very limited number of qualified instrument technicians. Even then, sizable differences in barometer readings will often be reported. In some tests, variations up to 30 feet have been observed in practically simultaneous readings by different individuals.

In order to reduce this error as much as possible, the reading of the basic standard in the United Air Lines Instrument Shop is limited to only two men who are also responsible for the adjustment of the sub-standard reference instrument. This sub-standard instrument is an ordinary sensitive altimeter from which all extraneous parts have been removed so that it is less affected by friction, balance, and other errors. The

instrument mechanics who make adjustments on the indicating instruments then refer only to this sub-standard unit.

Instrumental Limitations

The instrumental errors of airline flight and station altimeters are held to tolerances equal to or better than those specified by the military services and by the instrument manufacturers. For instance, the calibration errors of flight altimeters for low altitudes, that is up to 6000 feet, are held to ±15 feet. It will be seen that this permits a maximum possible overall difference between any two instruments of 30 feet, yet this tolerance is considerably less than that permitted by the military services. Above 6000 feet, the tolerances are as given in Table 1.

Table 1

True Pressure Altitude Feet	Permissible Error Feet
8000	±30
10000	±50
12000	±75
15000	±120
20000	±200

The mechanical balance of the indicating instruments has been found to be of particular importance. The linkage and other component parts of an aircraft altimeter assume many different positions with respect to one another while being subjected to a total pressure variation equivalent to the extreme range of the instrument. For a considerable period of time, it was believed only necessary to carefully balance an altimeter with the various elements of the mechanism in the position which they assume at or near sea level. Airline operation has proved that this is not adequate and the mechanical balance of all aircraft altimeters used on the airline with which the authors are associated is now checked at 12 different pressures. Starting at 2000 feet, the instrument must balance within the proper limits for four different positions at pressures equivalent to 2000, 2250, 2500, and 2750 feet, respectively. A similar check is also made starting at 6000 feet and again beginning at 10,000 feet.

In order to make the instruments come within the proper balance tolerances at all of these points, it is necessary to individually balance many of the component parts of the instrument. The present balance tolerances for any of the above positions and pressures is 12 feet for one type of instrument and 20 feet for another. Prior to the time when this procedure was put into effect, it was not unusual for an instrument to balance within 10 feet for some given pressure and have as much as 45 feet balance error at another pressure.

Personnel Errors

That personnel errors are a major factor can easily be understood when it is realized that a great many different persons may influence the accuracy each time the dispatcher transmits to the pilot the barometric pressure reading. (a) The basic standard must have been correctly read and this reading accurately transferred to the sub-standard. (b) The instrument mechanic must have carefully adjusted each of the three instruments involved (the station altimeter and the two instruments in the aircraft) to conform to the prescribed tolerances of calibration, friction, balance, hysteresis, etc. (c) The ground station altimeter must have been originally adjusted to be correct for the station to which it is to be assigned and for the elevation at which it is to be located above the field. (d) The dispatcher must read his instrument carefully to make certain any friction effects are eliminated with vibration, and that the average true static pressure existed. Gusty wind conditions can easily cause errors of the order of 45 or 50 feet due to the variation in static pressure with the gusts. (e) Finally, the pilots must properly adjust their instruments to coincide with the barometric pressure the dispatcher has transmitted to them.

As an indication of the magnitude of personnel errors, a check was recently made in the following manner: Two ground station instruments were given identical calibrations and were matched as carefully as possible in every respect in the same instrument shop. These instruments were then installed in two different dispatch offices at this same field. The readings of the dispatchers using these two instruments were obtained simultaneously by telephone for a period of 45 consecutive days. Seven different dispatchers were involved in taking the readings. During this time, a maximum difference of .015 inches of mercury was recorded between simultaneous readings. This is equivalent to approximately 15 feet. This close agreement was considered outstanding and is believed to be better than the average which is incurred in normal service when no unusual attempt is made to control the readings.

The purpose of the foregoing is simply to indicate that in using barometric pressure as a means for determining altitude and with the equipment now available, there are such a large number of variables involved that exact coordination is impossible. This means that each one of these variables must be controlled and understood. Even then the overall summation of these variables can at any particular time, amount to a considerable error. This error is perhaps much greater than would be imagined by one who is accustomed to thinking in terms of a single instrument operating under extremely well controlled conditions. For instance, in some of the early blind landing tests the sensitive altimeter was used for making the ground contact in landing. However, in this case the airplane simply took off, circled the field, and landed. During such a test, the

pilot could depend upon his sensitive altimeter to indicate when he was in contact with the ground again within ±4 or 5 feet. This is an entirely different situation than that which exists on the airlines.

In order to determine and to control the actual existing spread of altimeter readings, United Air Lines has set up a procedure which has been of particular benefit in correlating the readings of ground and flight altimeter equipment over the entire system. This procedure is, of course, in addition to the regular routine inspections. On one designated day each month, all stations record the indication of the flight altimeters of each plane at that particular station during a 24 hour period. The station altimeter barometric reading is used as the basis for setting the aircraft instruments and the indication of each in actual feet of elevation is then recorded and sent to a central office. This office then plots by stations, the amount by which the instrument reading was in error from the true station elevation. This graphical representation, when completed, indicates how closely the airplane instrument indications are grouping relative to any particular station. Further, if the pattern for any given station is such that it is high or low with respect to the zero error line, it is obvious that the station altimeter is not properly adjusted.

In order to detect individual aircraft instruments which are not within the prescribed tolerances, any instrument readings which are outside the normal ±40 foot tolerance are designated by airplane number. Thus, if the chart shows that an altimeter in a certain airplane, was outside the limit for two or three different stations, it is quite evident that that instrument is out of adjustment.

A similar graphical representation is maintained for each station by months. This gives a good indication of the trend of a station altimeter at any given location. Station altimeters having excessive drift are easily detected by this chart.

Thus it can be seen that it is easy to determine from these graphical representations, the degree of correlation of ground and airplane aircraft altimeters over an entire system and to effect corrections periodically. It is hoped the present tolerance of 40 feet can eventually be reduced, but it is doubtful if it will ever be very much improved for atmospheric pressure actuated altimeters because of the great number of variables involved. It is believed that a similar system will be found useful whenever a definite attempt is made to correlate the readings of all airline operators.

Book Reviews

Where Do We Go from Here? edited by JOSEPH MAYERS and BERNARD SPIERS; Frederick Muller, Ltd., London, 1938; 271 pages, 8s. 6d.

In one of a series of forward looking chapters on many subjects, Lt. Col. H. Burchall, general manager of Imperial Airways, gives his views on the immediate problems of commercial aviation. Outstanding in his review is his comment on the Empire Air Mail program which provides for the carrying of all first class mail to all parts of the British Empire by air. The extent of this project and its probable influence on international air transport has not received the recognition it deserves. It is a pioneering service that will undoubtedly establish a precedent for other countries to follow. He predicts that all letter mail will be carried by air without surcharge on the main world air routes; he looks forward to an increase in night flying in long distance operation, and believes the Atlantic and Pacific and even the North Pole will be crossed by numerous services using airplanes and airships.

Transpacific Flight, by DICK MORGAN; John H. Hopkins, Inc., New York, 1938; 248 pages, $2.00.

Wings over the Pacific, by LEWIS E. THEISS; W. A. Wilde Company, Boston, 1938; 304 pages, $2.00.

For several years hardly a month has passed without a new book being published on some part of the Pan American air route in Central and South America. Apparently the romancers and the travel writers are beginning to turn their attention to the Pacific operation of the Clippers as a new field for their endeavors.

The first of these books is pure fiction of the thriller type. Epidemics, women spies, aerial holdups, and theft of "formulas" for mysterious new gyropilots are all part of the romance written with the lurid embellishments of a Sunday supplement.

Theiss has written a book of an entirely different kind. He adopts the style of "carrying a message to Garcia" and weaves through the chapters the story of a Pan American pilot who is given a secret message by the Secretary of State to carry to an American secret service agent in the Far East. A fight to the death with a Japanese at the Midway Island swimming beach; being knocked unconscious by lightning that strikes the Clipper's antennae; overcoming icing conditions on a flight up a Chinese river—these incidents give added interest to what would otherwise be a well-informed and interesting story of a flight from Washington, D. C., to Hong Kong.

It is quite evident that, as the author says in the preface, the manuscript was carefully checked by the Pan American staff before publication. Otherwise one would not expect the details of a flight across the Pacific to be so accurate. By adopting a narrative style, the author has given human interest to a story of an exceptional flight. He is a keen observer, a fluent writer, and introduces a new technique in travel books. The operation of these large flying boats, the island ports en route, and many of the striking characteristics of an over-ocean flight are described. To those who plan to make the trans-Pacific flight, the book will give anticipatory pleasure; to those who cannot it gives a vivid picture of a flight on one of the clippers that fly the Pacific.

Effect of Air Movement on Combustion Rates in Spark-Ignition Engines

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Presented at the Power Plants Session, Seventh Annual Meeting, I. Ae. S.
January 26, 1939

Introduction

AIR movement within the combustion chamber of an internal-combustion engine can be divided into two general classifications: (1) air swirl and (2) air turbulence. Air swirl is defined as a regular rotation, as a whole, of the charge within the cylinder or the combustion chamber. Air turbulence is defined as irregular movement of the charge within the cylinder or the combustion chamber; turbulence may be either small scale or large scale. The air movement may be produced during the induction period, in which case it is called "induced" air movement; or it may be produced by forcing the charge through a restricting passage within the cylinder or the combustion chamber during the compression stroke, in which case it is called "forced" air movement.

In spark-ignition engines for aircraft, the necessity of a simple combustion-chamber shape to provide high volumetric efficiencies and adequate cooling has resulted in little attention being paid to forced airflow. Since, however, the air or the charge enters the cylinder at high velocities, a certain amount of induced air movement is always produced in the cylinder and the combustion chamber. This movement, once started, persists to a varying degree during the entire compression stroke.

Air movement within the engine cylinder has several different effects on the combustion of the charge. It may effect the homogeneity of the mixture, the rate of heat transfer from the mixture to the combustion chamber walls, and the rate of combustion when the movement persists through the combustion period. The first two effects may, in themselves, affect the combustion rate.

It is the purpose of this paper to present data obtained at the Langley Memorial Aeronautical Laboratory illustrating the two different classifications of air movement and to present data that show some of the effects of these movements on the rates and regularity of combustion.

Apparatus and Methods

The investigation was conducted with the N.A.C.A. glass-cylinder engine and the N.A.C.A. combustion apparatus. These have been described in references 1 and 2. The glass-cylinder engine (Fig. 1) consists of a single-cylinder unit upon which a glass cylinder has been mounted above the regular cylinder. An extension is mounted on the piston in the metal cylinder. This extension is of sufficient length so that the air is inducted, compressed, expanded, and exhausted from the glass cylinder in the normal manner of the conventional engine. The air movement is recorded by taking high-speed motion pictures (2000 to 2500 frames per second) of feathers inducted with the incoming air. The air movement from 40° b.t.c. to 40° a.t.c. is not visible. Fuel can also be injected during the induction stroke so that the mixing of the fuel and the air can be studied. This engine is not fired.

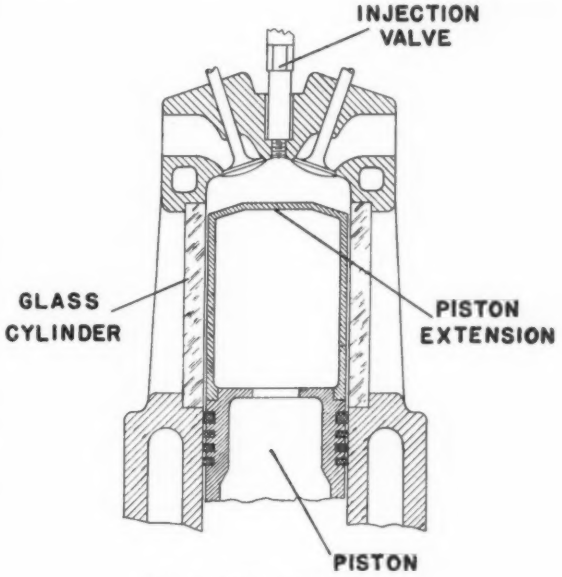

FIG. 1. Glass-cylinder engine.

The combustion apparatus (Fig. 2) also consists of a single-cylinder test engine. This engine has a large glass window in the combustion chamber so that the combustion process can be photographed. Time-pressure records are also taken using an optical indicator.[3] The fuel is injected into the combustion chamber on the intake stroke. Since the engine is operated under power for only one cycle, the two valves that serve for the inlet are also used for the exhaust, the glass window covering the side of the combustion

chamber normally occupied by the exhaust valves. The combustion chamber is of the pent-roof type.

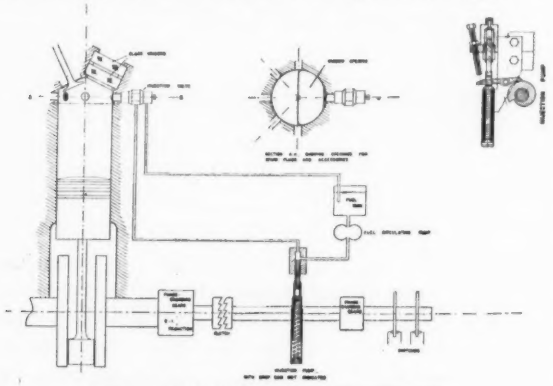

FIG. 2. N.A.C.A. combustion apparatus.

The air movement was varied in each piece of apparatus by placing shrouds on the inlet valves at different angles to the cylinder radius or by blocking off one of the inlet valves. The high-speed motion pictures taken through the glass cylinder showed the type of air movement obtained with each inlet-valve arrangement. Using the same arrangements on the combustion apparatus, the effects on the combustion were recorded by the combustion photographs and by the time-pressure records. Schlieren photography was used in the high-speed motion pictures of the combustion because experience has shown that such pictures are more clearly defined than direct photographs of the flame.[2] Fig. 3 shows the various inlet-valve arrangements tested.

The fuel used in these tests was similar to CFR S-1 reference fuel. The injection valve, having four discharge orifices, was mounted so that the sprays were directed across the cylinder toward the intake valves and in the plane of the spark-plug openings (Fig. 2).

RESULTS AND DISCUSSION

In Table 1 is given a description of the air movement obtained with the different inlet-valve arrangements. The description is based on visual observation of the

TABLE 1

Inlet-Valve Arrangement	Engine Stroke	Description of Air Movement	Dominating Air Movement
A	Intake	Undirected air entering the cylinder causes disorderly turbulence of marked intensity throughout the stroke.	Turbulence
	Compression	Turbulence gradually subsides, most of it disappearing before end of stroke.	Turbulence
	Expansion	Last of turbulence dies out	Turbulence
	Exhaust	Quiescent air is expelled from the cylinder	None
B	Intake	Entering air is directed by the shrouds so that half of it starts to swirl about the cylinder axis in one direction and half in the other. The meeting of these two air streams causes violent turbulence. Prevented from orderly swirl as a whole in either direction, the air goes slowly down along the cylinder wall, turns and flows over the piston top and then up the other side of the cylinder and across the head to the starting point. This vertical swirl begins about the middle of the stroke but is not fully established until nearly the end of the stroke.	Turbulence, changing to vertical swirl
	Compression	Slow vertical swirl accompanied by turbulence, both decreasing in intensity.	Vertical swirl
	Expansion	No orderly movement. Last of turbulence dies out.	Turbulence
	Exhaust	Quiescent air is expelled from the cylinder.	None
C	Intake	The air swirls about the cylinder axis. There is also strong turbulence, probably because one intake valve discharges air directly toward the other.	Turbulence, changing to horizontal swirl
	Compression	Turbulence subsides. Rate of swirl decreases.	Horizontal swirl
	Expansion	Last of turbulence dies out. Swirl continues, but at decreasing rate.	Horizontal swirl
	Exhaust	Air continues to swirl until it is expelled.	Horizontal swirl
D	Intake	Air from one inlet valve starts to swirl about the cylinder axis, while air from the other valve sets up a vertical swirl. The result is a combined horizontal and vertical swirl, with more turbulence than with any other inlet-valve arrangement which produces a horizontal swirl. The vertical swirl predominates during the first two-thirds of the intake stroke, after which the horizontal swirl is more pronounced.	Vertical swirl changing to horizontal swirl
	Compression	Vertical swirl dies out, leaving slow horizontal swirl with turbulence.	Horizontal swirl
	Expansion	Horizontal swirl continues at decreasing rate. Last of turbulence dies out.	Horizontal swirl
	Exhaust	Air continues to swirl until it is expelled.	Horizontal swirl

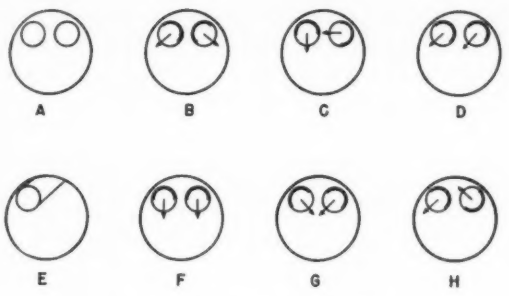

FIG. 3. Inlet-valve arrangements.

high-speed motion pictures of the movement of the feathers within the engine cylinder. The data are necessarily qualitative rather than quantitative. In general it can be said that arrangements A, B, and G gave the greatest degree of turbulence and that arrangement A gave little if any indication of air swirl. Next to A, condition B gave the least swirl. Condition H gave the greatest degree of swirl and the least turbulence. Condition C gave the next highest degree of swirl. In both these cases the swirl was in the horizontal plane. As is to be expected, the horizontal swirl persisted to a greater degree throughout the compression stroke and the expansion stroke than did the vertical swirl. In no case did strong turbulence as indicated by the motion of the feathers persist throughout the compression stroke. The decrease in the turbulent motion during the compression stroke was always noticeable, although in some cases the turbulence persisted into the expansion stroke.

From a comparison of the air-movement photographs with the photographs of the combustion when both are projected as motion pictures, it seems that the turbulent motion is not of sufficient rapidity to have much effect on the rate of combustion or on the irregularity of the combustion front. The higher degree swirl, however, appears to be sufficiently rapid to appreciably displace the flame front during its traverse across the combustion chamber.

The data presented do not give any clue as to the existence or lack of existence of turbulence that was too small to affect the motion of the feathers. If such small-scale turbulence exists, its effect on combustion must be the subject of subsequent research.

The effects of the air movement on the combustion must be considered from two standpoints, as has been mentioned previously—the effect on the mixing of the fuel and air and the effect on the transmission of the combustion front during the combustion period. In the present tests, the results do not entirely separate the two effects, but show only the overall effect on the combustion front as obtained from the Schlieren records and on the time-pressure record as given in the indicator cards.

The effects of the air movement on the combustion are more apparent from the time-pressure records than

TABLE 1 (*Continued*)

E	Intake	The shape of the intake passage causes the air stream from the single unshrouded valve to pass to one side of the cylinder axis and be slanted downward about 45°. During the early part of the stroke the air moves in a swirl, the plane of which is slanted across the cylinder. There is also some turbulence at this stage. Gradually the plane of movement becomes horizontal, resulting in a rapid swirl about the cylinder axis, and the amount of turbulence is greatly reduced.	Slanted swirl changing to horizontal swirl
	Compression	Swirl continues at decreasing rate. Turbulence dies out.	Horizontal swirl
	Expansion	Swirl continues at decreasing rate.	Horizontal swirl
	Exhaust	Air continues to swirl until it is expelled.	Horizontal swirl
F	Intake	Air moves in a vertical swirl as previously described, but much faster and with less turbulence.	Vertical swirl
	Compression	Vertical swirl continues at decreasing rate. Turbulence decreases.	Vertical swirl
	Expansion	No swirl. Last of turbulence dies out.	Turbulence
	Exhaust	Quiescent air is expelled.	None
G	Intake	Violent turbulence during the first half of stroke, followed by a slow vertical swirl with some turbulence. Vertical swirl more marked than with arrangement B.	Vertical swirl
	Compression	Slow vertical swirl with turbulence.	Vertical swirl
	Expansion	No swirl. Last of turbulence dies out.	Turbulence
	Exhaust	Quiescent air is expelled.	None
H	Intake	Air swirls rapidly about the cylinder axis. Maximum rate occurs at about 110° after top center when it is about 5.5 times the crank speed. Average rate for entire cycle is about twice the crank speed. There is very little turbulence, least of any conditions tested.	Horizontal swirl
	Compression	Air swirls at reducing rate. Turbulence dies out.	Horizontal swirl
	Expansion	Air swirls at slowly reducing rate.	Horizontal swirl
	Exhaust	Air continues to swirl until expelled.	Horizontal swirl

from the combustion photographs. In Fig. 4 are shown the time-pressure records obtained at an engine speed of 500 r.p.m. with two spark plugs. There are two general effects noticeable—the changes in the time required to complete the combustion and the changes in the regularity of combustion. The combustion was the slowest with the two arrangements giving the maximum amount of visible turbulence in combination with very little or no air swirl (B and A). With all the other settings of the shrouds and with the single inlet valve, the rate of burning was considerably increased. The increase in the rate of burning was about the same with these six arrangements (C through H) although the degree of swirl and the persistency of the swirl through the compression stroke varied.

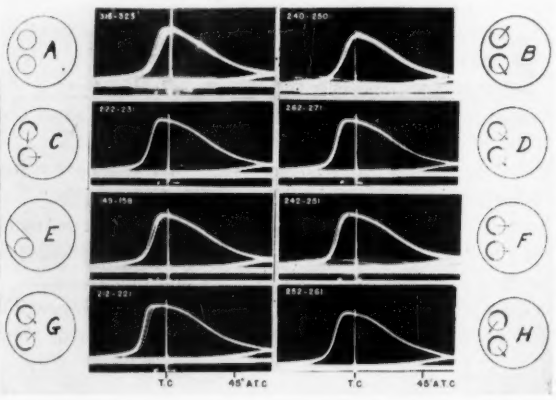

FIG. 4. Effect of gas movement on cycle reproducibility. Engine speed, 500 r.p.m.; two spark plugs.

The regularity of the combustion is shown by the spread of the time-pressure records for each condition. In each case, records of at least 10 combustion cycles are superimposed in making the photographic print (as indicated by the record numbers). The greatest amount of cyclic variation was obtained with condition A, in which there was no swirl; and the least for condition H, in which the swirl was a maximum and the turbulence a minimum, and condition C, which had the next highest swirl.

The effect of turbulence and swirl on the regularity of combustion is more strikingly illustrated in Fig. 5, showing the results of tests in which only one spark plug was used. In this case, the increased rate of combustion was accompanied by a suppression of knock. This suppression of knock is also visible to a lesser extent in the preceding figure. Knocking combustion is indicated by the vibrations set up in the expansion line at about peak pressure.

The combustion irregularity and the time of combustion for the different valve arrangements are tabulated in Table 2. The combustion irregularity is given as the spread of the indicator cards in crankshaft degrees obtained from Fig. 4. The time of combustion was obtained from the same figure and gives the interval from the ignition spark to the end of combustion as indicated by the time-pressure records. The following facts are indicated from this table: (1) Combustion was most irregular when the turbulence was greatest (conditions

TABLE 2

Effect of Inlet-Valve Arrangement on Regularity and on Combustion Time

Inlet-Valve Arrangement	Combustion Irregularity, Crankshaft Degrees	Combustion Time, Crankshaft Degrees
A	6	28
B	2	30
C	0	23
D	1	23
E	2	23
F	1	23
G	3	21
H	0	23

A and G); (2) combustion was slowest when the air swirl was absent or of smallest intensity (conditions A and B); and (3) combustion was most regular when the air swirl was at a maximum (condition H to C).

It has been most generally conceded that the chief effect of turbulence on combustion speed within a spark-ignition engine has been to increase the rate of burning. This explanation has been given as the reason that increasing engine speed (which increases the rate of air flow through the inlet valves) increases the rate of burning (references 4, 5, and 6), the assumption being that the increased velocity through the inlet valves is accompanied by a corresponding increase in turbulence. Unfortunately, the exact mechanism by which the turbulence increases the flame velocity has not lent itself to experimental investigation. In most of the tests on engines, experiments to vary the turbulence have consisted of varying the engine speed. Although such

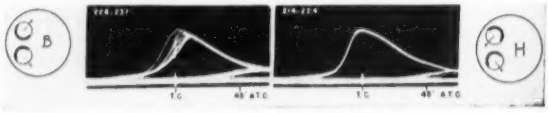

FIG. 5. Effect of gas movement on cycle reproducibility. Engine speed, 500 r.p.m.; one spark plug.

tests may be indicative, they cannot be considered to be conclusive because factors other than the turbulence are varied and the variation in turbulence has, of necessity, been assumed rather than measured. It is true that tests conducted in bombs have shown that a fan turning at a comparatively high speed within the bomb increases the rate of burning of the mixture. However, it must be remembered that, whereas in the case of slow-burning mixtures the air movement may more than

double the combustion speed, in the case of rapidly burning mixtures the airflow has a decidedly smaller effect on the combustion speed.[7] In addition, in the reported bomb tests, the combustion speed in no cases reached the velocity reached within the engine combustion chamber.

The present results may have been affected by a small scale turbulence unrecorded by the moving feathers. Such a microturbulence has been suggested as the mechanism that causes the combustion rate to increase with engine speed. If such is the case, the turbulence must be sufficiently small so that its effects on the combustion front are not visible unless microphotography is employed. In the present tests, the Schlieren photographs have not shown any more irregularity in the combustion front with the valve settings giving the greatest amount of turbulence than with those in which the turbulence is least. Examination of numerous photographs indicates that the variation in combustion front for successive records taken under the same conditions masks any variation that occurs with the different inlet-valve arrangements. Fig. 6 shows the variation that is apt to occur.

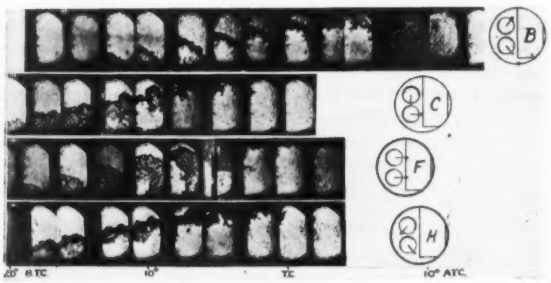

FIG. 6. Effect of gas movement on combustion. Engine speed, 500 r.p.m.; one spark plug.

It is pointed out again that the visual observation of the motion-picture records of the airflow indicates that such turbulence that is seen to exist throughout the compression stroke has so decreased in intensity by the time the piston approaches top center that it hardly seems that it could have much effect on the rate of combustion. Consequently, it is concluded, that such effects of turbulence as have been observed in these tests are probably results of increased or decreased homogeneity of the fuel-air mixture.

The present tests have shown that increasing the velocity of the air as it enters the engine cylinder does not necessarily increase the rate of combustion. (Compare A and B.) The conclusion is drawn from these results and those of other workers that, although turbulence may be the cause of the increased combustion rate with engine speed, the explanation must be accepted as a theory rather than a fact and the possible effects of other causes, such as the time factor, must not be discarded.

The most interesting result obtained from the present tests is the fact that, with spark ignition, exceedingly regular combustion can be obtained by the correct use of air swirl within the engine cylinder. The importance of this fact is that, by increasing the regularity of combustion, the knocking limit can be approached more closely than is the case with irregular combustion. As a result, the maximum permissible power with any given fuel can be increased and the minimum permissible fuel consumption can be decreased.

The increased reproducibility obtained with the settings giving an air swirl is probably the result of improved mixing of the fuel and the air. The best reproducibility was obtained with those conditions in which the air not only traveled through the spray as it was being injected but continued to swirl after injection was completed. It is possible that, in a carburetor engine or in an engine in which the fuel is injected into the intake manifold, the absence of cyclic variation that was obtained with conditions C and H would not be realized. Tests at this laboratory with a CFR engine have shown a decrease in cyclic variation with a shrouded inlet valve but not to the extent shown in the results presented herein. Having the mixture sweep past the spark plug may also be beneficial in that this movement prevents pockets of overlean or overrich mixtures remaining in the vicinity of the plug and so affecting the combustion propagation.

In actual engine design, shrouded valves are seldom used because of the decrease in volumetric efficiency at high engine speeds. The inlet passage through the cylinder head can be so designed, however, as to promote air swirl without sacrificing volumetric efficiency. The use of a sleeve valve instead of poppet valves offers considerable amount of leeway in the direction and amount of air swirl produced without sacrificing volumetric efficiency.

CONCLUSIONS

The following conclusions are drawn from the test results presented:

(1) Air swirl or air turbulence produced during the induction stroke of a four-cycle engine persists to a considerable degree through the compression stroke and in some cases through the expansion stroke.

(2) Increasing the velocity of the incoming air does not necessarily increase the rate of combustion.

(3) As the amount of air swirl was increased, the cyclic variation was decreased.

(4) An increase in the rate of combustion may be accompanied by a decrease in the tendency of the fuel to knock, other engine conditions remaining constant.

REFERENCES

[1] Lee, Dana W., *A Study of Air Flow in an Engine Cylinder*, N.A.C.A. Technical Report No. 653, 1939.

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[2] Rothrock, A. M., and Spencer, R. C.: *The Influence of Directed Air Flow on Combustion in a Spark-Ignition Engine*, N.A.C.A. Technical Report No. 657, 1939.

[3] Tozier, Robert E., *The N.A.C.A. Optical Engine Indicator*, N.A.C.A. Technical Note No. 634, 1938.

[4] Marvin, Charles F., Jr., Wharton, Armistead, and Roeder, Carl H., *Further Studies of Flame Movement in an Engine Cylinder*, N.A.C.A. Technical Report No. 556, 1936.

[5] Bouchard, C. L., Taylor, C. Fayette, and Taylor, E. S., *Variables Affecting Flame Speed in the Otto-Cycle Engine*, S.A.E. Journal, Vol. 41, No. 5, pages 514–520, November, 1937.

[6] Schnauffer, Kurt, *Combustion Velocity of Benzene-Benzol-Air Mixtures in High-Speed Internal-Combustion Engines*, N.A.C.A. Technical Memorandum No. 668, 1932.

[7] David, W. T., *Turbulence in Internal Combustion Engines*, The Engineer, Vol. CXLIV, No. 3755, pages 733–734, December 31, 1937.

Book Reviews

Elementary Matrices and Some Applications to Dynamics and Differential Equations, by R. A. FRAZER, W. J. DUNCAN, and A. R. COLLAR; Cambridge University Press, Cambridge, The MacMillan Company, New York, 1938; 401 pages, $8.50.

In the last fifteen years the theory of matrices has found a considerable field of application in mathematical physics and it has become a useful tool in the treatment of quantum mechanics. More recently matrices have been applied to engineering problems, both in the theory of electric networks and in problems of vibration. A series of articles published in the recent years by the authors of this book has contributed very much to spreading more knowledge on matrix theories and their possibilities in mechanical engineering.

There are only a few published treatises on matrices and none of them treat the subject with special reference to its application to differential equations and classical mechanics. The present book provides such a treatise and fulfills at the same time the task of introducing the subject to students of applied mathematics who have no previous knowledge of matrices. Although the scope of the book is elementary, occasional discussions of advanced questions are not avoided.

Special emphasis should perhaps be laid on the fact that matrices are primarily useful for two reasons: They provide a concise notation for the concept of linear transformation of a group of quantities into another and from this viewpoint they generalize the concept of the linear operator. It furnishes for instance a convenient way for writing a system of linear differential equations and its formal solution. The other advantage is that matrices lead naturally to a most convenient tabular arrangement of numerical data, so that formal expressions of solutions can be readily used for numerical computation.

The three first chapters introduce fundamental definitions, powers of matrices, polynomials, series of matrices, the operation of differentiation and integration, the properties of so-called lambda matrices whose elements are functions of a parameter, and finally the important concept of equivalent matrices.

Chapter IV deals with numerical illustrations of algebraic motion, such as the calculation of determinants of the solution of simultaneous algebraic equations.

The next three chapters are devoted to the applications to linear differential equations with constant or variable coefficients, with special reference to numerical solutions.

The rest of the book from Chapter VIII to Chapter XIII deals entirely with dynamical problems; classical dynamics with Lagrange's and Hamilton's equations are written in matrix notations; the theory of small oscillations, the orthogonality of the modes, and Rayleigh's principle are derived.

The matrix notation is especially convenient when methods of iteration are used in the numerical solutions of linear dynamical problems. The method in its fundamental principle is well known to engineers. It was developed long ago for the calculation of characteristic values and functions in buckling and vibration problems of beams by Vianello, Engesse, and Stodola. In systems with a finite number of degrees of freedom the mode of highest or lowest frequency can be calculated directly by the iteration process which here amounts to the evaluation of the successive powers of the matrix characterizing the dynamical system.

The method of iteration is also extended to the case where the oscillations are damped and proves extremely useful for the calculation of the complex roots of the characteristic equation. The method is applied numerically to several examples and among others to the torsional oscillations of a multicylinder engine and the damped motion of an airplane wing in an airstream.

Of particular interest are the authors' original contributions in the last chapters dealing with the properties of dynamical systems in which solid (Coulomb) friction occurs. Such systems are not linear, but lead to recurrence relations between the successive phases of motion. The properties of these recurrence relations are here investigated by means of the matrix tool. Stability conditions are derived and the theory applied to many numerical examples of airplane flutter.

M. BIOT
Columbia University

The Flight of Birds, by C. HORTON-SMITH; H. F. & G. Witherby, Ltd., London; 182 pages, 7s. 6d.

Before the advent of high-speed motion pictures, observers of the movement of rapidly moving objects had to rely largely on keen eyesight. In this book the author has taken full advantage of new scientific devices and presents a discussion of bird flight of considerable interest to the aeronautical specialist.

A chapter is devoted to the means by which birds make use of slots, formed by the interstices between feathers, in delaying the stalling of their wings. He gives a plausible explanation of the operation of the slots and explains their effectiveness by analogy with the corresponding devices on airplane wings.

Aeronautical nomenclature is used throughout; so much that a short glossary of terms is given for the layman.

The book covers the subject of bird flight from the days of the earliest investigators to the present time. While there is considerable material on the anatomical structure of birds, it is important to know just how they carry out their various maneuvers. The aeronautical engineer will find some striking similarities between the mechanisms of flapping and soaring flight and that of mechanical flight. The chapter on "The Alighting and Rising Bird" is of particular interest to the aeronautical engineer.

The author is primarily a zoologist and many of the terms used are foreign to the engineer. However, the material on the mechanism of flight will be interesting to any aeronautical specialist.

Measurement of Stiffener Stresses and Effective Widths in Stiffened Panels

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Presented at the Meeting of the Los Angeles Branch of the I. Ae. S.
October 1, 1938

SUMMARY

In the design of a stressed skin metal airplane it is essential that correct stiffener stresses and effective widths of skin acting with the stiffener be known in order to insure that fictitious margins of safety in wing and fuselage analyses are not shown. In this paper the problem of determining these stresses and effective widths is discussed and some experimental results from Lockheed tests are presented. An experimental method is described which makes possible the accurate determination of these quantities, employing extensometer strain data interpreted by means of a compression stress-strain curve for the stiffener.

NOMENCLATURE

t_s = Skin thickness (inches).
P_T = Total panel load in lbs.
σ_{ST} = Stiffener stress in lbs. per sq.in.
A_{ST} = Stiffener area in sq.in.
b = Stiffener spacing (inches).
n = Number of equal bays in test panel.
W_e = Total effective width of skin on test panel (inches).
w_e = Half the total effective width acting with each stiffener (inches).
L = Panel length (inches).
$\lambda = \sqrt{E/\sigma_{ST}}\ (t_s/b)$ where E is the modulus of elasticity of the skin and σ_{ST} is equal to σ_{skin} at the stiffener (reference 1).

COMPARISON OF DESIGN METHODS

A NUMBER of investigators have developed curves for the effective width of buckled sheets under pure compression, several of which are plotted in Fig. 1 in the manner developed by Sechler.[1] Three types of curves appear. Curves of the first type, including curves 4 to 7, are intended to follow the progress of a certain type of panel as the panel load is increased, defining the fashion in which the effective width decreases after initial buckling. Curves of the second type, such as curve 1, are failure curves giving the effective widths for values of λ corresponding to edge stresses in the sheet that are equal to the compressive yield strength. Curves 2 and 3 are an intermediate type and are intended to approximate the effective width at all stresses. Without exception, the curves have been developed for unstiffened panels, and the results have been applied to stiffened panels under the assumption that the edge support used in the determination of the curves is comparable to that offered by the stiffener.

In the design of semi-monocoque structures it is common practice to subject small representative panels to destruction tests in compression and record the ultimate load attained. An effective width curve is then selected and a series of approximations is made to determine the ultimate stiffener stress and effective width of skin which will satisfy the curve selected and the ultimate panel load. Thus the accuracy with which the stiffener stress can be determined depends entirely on the selection of the proper curve.

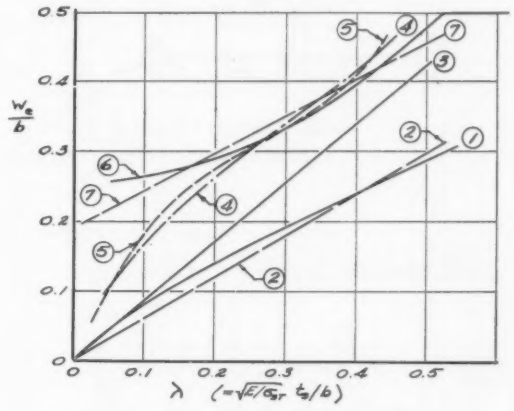


FIG. 1. Various effective width curves.

1. Sechler's "Failure" Curve[1].
2. A.N.C.-5 curve[4] for free edges of stiffened panels.
3. A.N.C.-5 curve[4] for skin between stiffeners.
4. Marguerre's theoretical curve[5] for sheet with simply supported edges.
5. Lahde and Wagner experimental curve[6].
6. Sechler's "Cosine" curve[1].
7. Th. von Kármán's curve[7] with constant supplied by Marguerre[5]. $(w_e/b = A_1\lambda + A_2;\ A_1 = 1.54,\ A_2 = 0.19.)$

From Fig. 1 it may be seen that curves of the first type will give a high effective width and low stiffener stress for a test panel and the second type will give a low effective width and a high stiffener stress. The intermediate type of curve, such as 2 or 3, is a compromise of the first two types and probably gives better results over a wide range of test panels. The results from any of these curves obtained by the aforementioned method of approximation are useful for preliminary calculations but are not sufficiently accurate for a final analysis. The errors that arise from the application of this method will be demonstrated by a simple example.

Allowable bending moments are calculated for the simplified wing section of Fig. 2., using the results of

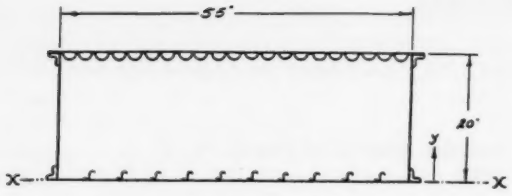
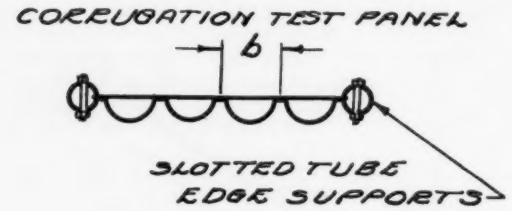


FIG. 2. Cross-section of box beam.

tests of panels similar to those shown in Fig. 3. The following four assumptions of effective width are compared:

(1) Fully effective compression skin.
(2) Fully ineffective compression skin.
(3) The A.N.C.-5 curve (number 3 of Fig. 1).
(4) Actual measured values obtained from panel tests.



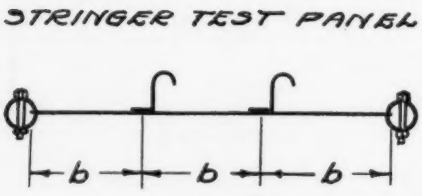


FIG. 3. Stiffened test panels.

The first two assumptions are hardly reasonable, but are included to indicate the extreme possible variation in bending moments. The properties of the box beam of Fig. 2 are given below:

Lower surface:
Skin thickness, $t_s = 0.051$ in.
Stiffener spacing, $b = 5$ in.
Stiffener area, total, $A_{ST} = 1.04$ sq.in.
Upper surface:
Skin thickness, $t_s = 0.051$ in.
Corrugation thickness, $t_c = 0.064$ in.
Corrugation area, $A_c = 5.04$ sq.in.
Flanges:
Area = 1.0 sq.in. per flange.

The results of the calculations are summarized in Table 1.

It might appear that the determination of the allowable bending moment on the box beam in terms of stress and effective section properties is an unnecessary complication since all of the compression flange material is at the same distance from the neutral axis. In this case the use of only ultimate panel load data might be necessary. That is, the allowable bending moment is equal to the product of the allowable load on the compression flange and the distance between the flanges of the box. However, since the simple box was selected to show the variations caused by different methods of computing stress, no consideration of ultimate panel load is necessary. It must be evident that, in aircraft structures, the presence of combined bending and torsion, the use of dissimilar materials, and complicated sections make it necessary to deal with stress rather than with load at all times.

Although in the analysis of an airplane an assumption of full effective width of skin would be the least conservative, and an assumption of no effective width would be the most conservative, in panel tests the reverse is true. High assumed effective widths for test panels give low allowable stiffener stresses and hence low allowable bending moments on a section, and low assumed effective widths give high stresses and high allowable moments, as may be seen from Table 1. The

TABLE 1. ALLOWABLE BENDING MOMENTS ON BOX BEAM OF FIG. 2

I. Normal Condition (compression in top flange).*

Effective Width Assumption	e†	$(\sigma_{ST})_{ULT.}$	I/y (In.^{3})	M (Allowable) (In. Lbs.)
1. Full effective width	100	42,400	180	7.63×10^6
2. No effective width	0	62,500	127	7.81
3. A.N.C.-5 curve	48.5	50,900	153	7.78
4. Actual effective width	6.2	58,200	135	7.85

II. Inverted Condition (compression in bottom flange).

Effective Width Assumption	e	$(\sigma_{ST})_{ULT.}$	I/y (In.^{3})	M (Allowable) (In. Lbs.)
1. Full effective width	100	19,200	110	2.12×10^6
2. No effective width	0	89,500	56	4.98
3. A.N.C.-5 curve	25.5	46,200	70	3.22
4. Actual effective width	49.0	32,500	84	2.73

* To avoid obscuring the desired effect, the fact that the tension flange is critical through Condition I is ignored.
† e = per cent effectiveness of compression skin.

use of the A.N.C.-5 curve gives slightly conservative moments for one condition and about 25 percent unconservative moments for the other. Thus it is evident that accurate margins of safety depend upon accurate experimental determination of stiffener stresses and effective widths, not merely upon ultimate panel loads. For this reason it is desirable that some simple method for determining these quantities be available.

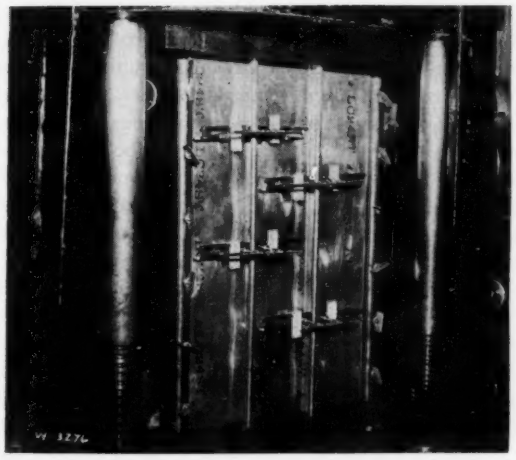


FIG. 4. Mounting extensometers on stringer panel.

MEASUREMENT OF STIFFENER STRESSES AND EFFECTIVE WIDTHS OF SKIN

The method presented herein was developed to determine accurately the stresses in various types of dural stiffeners and the effective width of skin acting at the stiffener stress. Stiffened test panels were constructed of dural sheet riveted to stringers or corrugated sheet as shown in Fig. 3. Accurate milling of the ends of the panels was necessary to insure a uniform deflection over the entire panel during the test. Huggenberger extensometers with a two centimeter gage length were mounted on the stiffeners by means of a brace in the case of the stringers (Fig. 4) and by means of suction cups in the case of the corrugations (Fig. 5). Steel edge tubes were clamped to the free edges of the panels in such a manner that they could carry no compression.

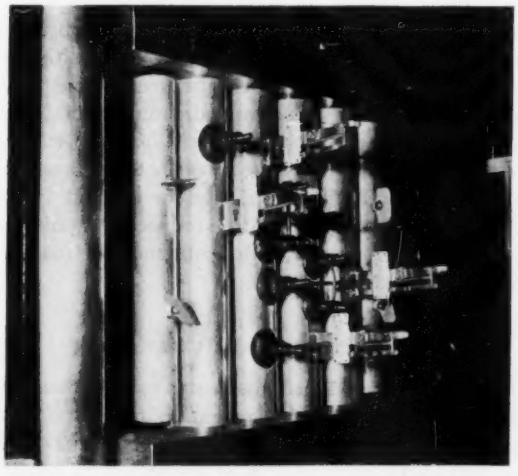


FIG. 5. Mounting extensometers on corrugation panel.

The properties of the test panels of Fig. 3 were as follows:

Corrugation panel:
- Corrugation area (incl. edges) = 1.085 sq.in.
- Full skin area = 0.510 sq.in.
- Ultimate load = 67,900 lbs.

Stringer panel:
- Stiffener area = 0.208 sq.in.
- Skin area = 0.765 sq.in.
- Ultimate load = 18,630 lbs.

The panels were tested flat ended in compression and extensometer strain data were obtained. From four to eight extensometers were mounted on each panel, depending upon its size, to insure that average results would be obtained.

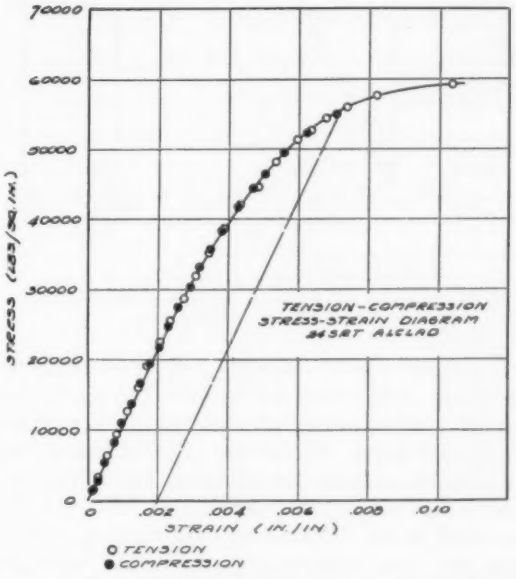


FIG. 6. Tension and compression stress-strain curves for .064 in. 24SRT alclad corrugation.

In order to convert stiffener strain into stress, it was necessary to determine the stress-strain relationship for the stiffeners alone in compression. Sections of stringers and corrugations sufficiently short to avoid column deflection were tested in compression and stress-strain curves were plotted from the data obtained. A comparison of the compression stress-strain curves with tension curves for the same sheet of material showed that for corrugations of 24SRT alclad the curves coincided as shown in Fig. 6. Test data to bear out this result are limited, but are in good agreement for the various thicknesses of corrugations tested. For the stringers, however, due principally to instability at high stresses, the defined yield point in compression was considerably below the yield point in tension as may be seen from the curves for a typical ex-

truded bulb angle stringer in Fig. 7. Part of this reduction may be attributed to a difference in tension and compression yield points in the case of some materials.

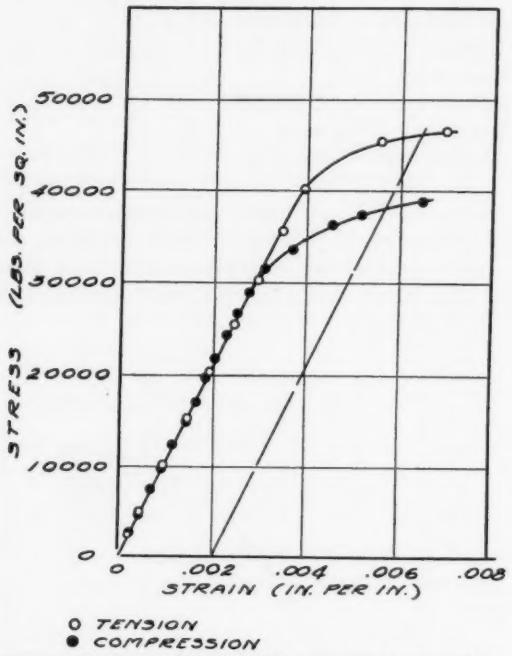


FIG. 7. Tension and compression stress-strain curves for a typical 24ST extruded stringer.

It was found that ordinarily a short specimen from which the stress-strain curve was determined failed through the same type of instability as the stiffener on the test panel. Should the types of failure differ, errors would arise in the interpretation of the strain data. The corrugations deflected in block compression until failure occurred by local buckling. Hence, since test data indicate that the 24SRT corrugated alclad material behaves the same in compression as in tension, it is permissible to interpret corrugation strain data from a tension curve for this material. However, the agreement of the tension and compression curves should be checked by further tests. If differences are found, compression curves must then be used in the interpretation of the strain data. Stringers failed by twisting or by local buckling, producing the type of compression curve shown in Fig. 7. Hence, it is necessary to make a compression test of a short specimen of each particular type of stringer used from which the panel strain may be converted into stiffener stress. Care must be taken in the interpretation of the strain data from long panels that fail as a column because of the presence of bending stresses. Two methods were used for the elimination of bending stresses. The first is based on the assumption, substantiated by test data, that the effective width is practically independent of length for L/b greater than one. Sufficiently short panels have been found to be completely free from column deflection and, hence, from bending stresses. Consequently, the stiffener stress for a long panel may be obtained from the stiffener stress *versus* panel load curve of a corresponding short panel, since the stiffener stress in a long panel at any load will be the same as the stress in the short panel at the same load. The second method, used principally on stringer panels, consists of mounting extensometers back to back on the stringers at their neutral axis, as shown in Fig. 4.

Having determined the stiffener stress, the calculation of the effective width of skin becomes a simple matter. The stiffener load is determined from the stiffener stress and area, and the difference between this load and the total panel load is carried by the skin. The effective width is then determined by dividing the skin load by the stiffener stress and the skin thickness. From this procedure the following equation results:

$$W_e = \frac{1}{t_s}\left(\frac{P_T}{\sigma_{ST}} - A_{ST}\right)$$

The effectiveness of the skin at the edge tubes must be determined to calculate the effective width of skin acting with each stiffener. For the corrugation panel shown in Fig. 3, all the edge skin outside the last rivet line may be assumed to be fully effective. Thus the determination of the ratio w_e/b is simplified to:

$$w_e/b = (W_e - \text{total edge skin})/2nb$$

The stringer panels as shown in Fig. 3 were constructed with three equal bays and from the tests it was evident that the shape and size of the waves in all three bays were identical. Therefore it may be assumed that an effective width of skin equal to half that at each stiffener is acting at each edge tube. Then:

$$w_e/b = W_e/2nb$$

The lateral support given a test panel by the edge tubes simulated that of a continuous panel since the wave shape and effective width of skin at the edge were identical to that adjacent to a stiffener. In the test panels an end fixity coefficient between 3 and 4 was obtained. This was determined from tests in the Euler range of panels of known L/ρ. However, in the airplane an end fixity coefficient between 1 and 2 is the maximum obtainable. Hence, to account for the difference, the test data must be reduced by some suitable method. Similarly, reductions must be made for material variations.

Experimental Results

The method developed above was applied to a large number of stringer and corrugation panels and consistent results were obtained throughout. Detailed calculations for a typical panel are shown in Table 2, and the results are plotted in Fig. 8. Skin load, effec-

tive width, and stiffener stress are plotted against panel load which is used as a parameter to obtain a simultaneous comparison of the behavior of the skin and stiffener. Fig. 9 is a similar plot for a typical corrugation panel.

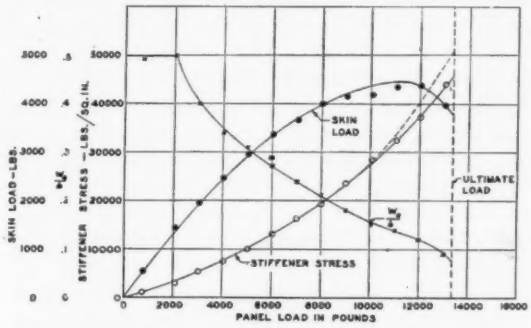


FIG. 8. Behavior of stringer panel under compression.

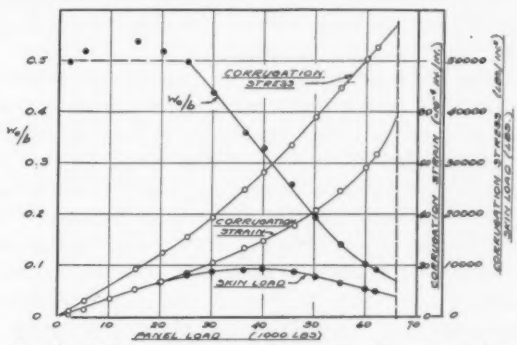


FIG. 9. Behavior of corrugation panel under compression.

In order to obtain ultimate stresses and effective widths, it is unnecessary to plot the results for each panel in such detail, but many important observations may be made from such a plot. From the effective width curve the initial buckling of the skin may be obtained by noting where the curve drops from a value of 0.5. The effective width may be obtained at all stresses thus aiding the stress analyst in calculating section properties. It is interesting to note that in both Fig. 8 and Fig. 9 the skin load reaches a maximum before the ultimate panel load is obtained. Whether the immediate cause is inter-rivet buckling or the use of weaker material for the skin, the early failure of the skin is undoubtedly due to the combined stresses from compression and bending exceeding the strength of the material. Thereafter, the skin not only fails to carry any increased load, but may eventually drop its load entirely. It would be expected that the effect of inter-rivet buckling on the stiffener stress and effective width curves would be very marked, but this is not always the case. Fig. 8 shows a marked decrease in skin load after inter-rivet buckling occurred at a panel load of about 11,000 lbs., but this sharp drop does not appear on Fig. 9 at the inter-rivet buckling stress of 46,000 lbs. per sq.in.

The method used by the authors for predicting inter-rivet buckling follows the suggestion of J. S. Newell,[2] except that instead of using the yield point in the Johnson-Euler type of curve, the Euler curve with the tangent modulus E_t, obtained from a tension stress-strain curve, is used. This method, suggested as early as 1889 by Engesser,[3] gives excellent agreement with column tests throughout the elastic and plastic range.

Two stiffener stress curves are shown in Fig. 8. The dotted curve is obtained by interpreting the stiffener strain data from a tension stress-strain curve and the other curve is plotted by interpretation from a compression curve. The use of the tension curve leads to an ultimate stiffener stress 12 percent higher than the

TABLE 2. SAMPLE CALCULATIONS FOR STRINGER PANEL

Panel Load Lbs.	Average Extensometer Reading	Stiffener Strain $\times 10^{-4}$ In./In.	*Corrected Strain $\times 10^{-4}$ In./In.	Stiffener Stress Lbs./Sq.In.	Stiffener Load Lbs.	Skin Load Lbs.	Effective Width Inches	$\frac{w_e}{b}$	λ
750	0.0	0.0	1.1	1100	230	520	14.8	0.49	0.609
2050	1.2	2.0	3.1	3000	620	1430	14.9	0.50	0.369
3000	2.5	4.1	5.2	5100	1050	1950	12.0	0.40	0.283
4000	3.9	6.5	7.6	7500	1550	2450	10.2	0.34	0.232
5000	5.5	9.1	10.2	10000	2060	2940	9.2	0.31	0.202
6000	7.3	12.1	13.2	13000	2680	3320	8.0	0.27	0.178
7000	9.3	15.4	16.5	16200	3340	3660	7.1	0.24	0.159
8000	11.3	18.7	19.8	19400	4000	4000	6.4	0.21	0.145
9000	13.9	23.1	24.2	23700	4880	4120	5.4	0.18	0.132
10050	17.4	28.9	30.0	28500	5880	4170	4.6	0.15	0.120
11050	20.8	34.5	35.6	32500	6700	4350	4.2	0.14	0.112
12000	25.7	42.6	43.7	37000	7620	4380	3.7	0.12	0.105
13000	35.2	58.4	59.5	44000	9060	3940	2.8	0.09	0.096
13360	Ultimate								

* Strain corrected for zero load.
Buckling between rivets occurred at a panel load between 11,000 and 12,000 lbs.

Stiffener = 0.051 24SRT alclad "J" section (1 inch deep)—
Tension Y.P. = 54,000 lbs. per sq.in.
Skin = 0.032 24ST alclad.
Length = 5 inches.
Stiffener spacing = 5 inches.
Total stiffener area = 2 × 0.103 = 0.206 sq.in.
Rivet spacing = 1 inch.
Average extensometer constant = 1.659×10^{-4} in./in.

correct stress and such an error would be serious in airplane design.

Large scatter in effective widths may be expected at low stiffener stresses since, in this case small differences between large numbers are used in the reduction of the data. Also small errors in initial extensometer readings will lead to large scatter. At high stresses, however, the scatter becomes small.

From the tests of more than fifty stringer panels a plot of w_e/b against the parameter λ was made and all the experimental curves were found to lie in the narrow range bounded by the two dotted curves of Fig. 10. Curve C is the plot of the average of all the results and shows the general shape of the curves obtained. The experimental points from Fig. 8 are shown in this plot to indicate the amount of scatter obtained in individual panel tests. Curves A and B are Sechler's curves and are included in the plot for purposes of comparison.

Four different stringers, two 24ST bulb angle extrusions and two 24SRT alclad "J" sections, were used with stringer spacings of five and six inches and skin thicknesses ranging from 0.032 to 0.064 in. The panel lengths ranged from 5 to 24 inches and a constant rivet spacing of one inch was used on all panels. The cross-sectional areas of the two bulb angles were 0.059 and 0.082 sq.in. and the areas of the two "J" sections were 0.103 and 0.115 sq.in. The radii of gyration were 0.204, 0.248, 0.392, and 0.481 inches, respectively.

Curve D, plotted from the results in Fig. 9, is typical of the behavior of skin on corrugation panels. The general shape of curves C and D is the same but differs markedly from that of any of the curves of Fig. 1. In the narrow range of b/t_s covered by the stringer panels the curves seemed to progress steadily to the right with decreasing b/t_s. In general, the same was true of the corrugation panels, although there were less data available on this type of stiffener. It may eventually become possible to plot a family of curves covering the entire range of b/t_s that will apply to most types of stiffeners. The curves presented should not be used for design purposes outside of the range of panels tested.

The use of the effective modulus of elasticity, which varies with the stress in the plastic region, in place of the initial modulus E in the parameter λ has been attempted but has not proved advantageous as yet.

It has long been suspected that ultimate stiffener stresses decreased with increasing skin thickness and by employing the method described above for the measurement of stiffener stresses, this effect has been found to be present. Physically, the effect can be visualized if the bending and torsional moments induced into the stiffener by the buckled skin are considered. Therefore, it is by no means correct to assume that a corrugation, for instance, will carry the same ultimate stress when covered with skin as it will when tested alone.

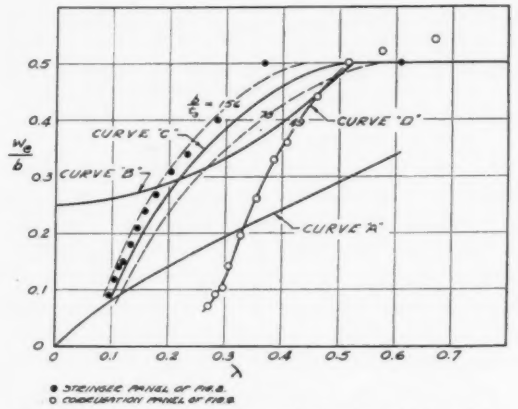


FIG. 10. Lockheed experimental effective width curves.

REFERENCES

[1] Sechler, E. E., *"Stress Distribution in Stiffened Panels under Compression,"* Journal of the Aeronautical Sciences, Vol. 4, No. 8, June, 1937.

[2] Newell, J. S., Letter to the Editor, Journal of the Aeronautical Sciences, Vol. 4, No. 6, April, 1937.

[3] Engesser, F., Zeitschrift für Architektur-Ingenieur Wesen, 1889, p. 455.

[4] A.N.C.-5, *"Strength of Aircraft Elements,"* Chapter 1, p. 37.

[5] Marguerre, Karl, *"The Apparent Width of the Plate in Compression,"* N.A.C.A. Technical Memorandum 833, July, 1937.

[6] Lahde, R., and Wagner, H., *"Experimental Studies of the Effective Width of Buckled Sheets,"* N.A.C.A. Technical Memorandum 814, December, 1936.

[7] von Kármán, Th., Sechler, E. E., and Donnell, L. H., *"The Strength of Thin Plates in Compression,"* Applied Mechanics Transactions of the A.S.M.E., June, 1932.

Flat-Bottom Corrugations under Combined Loading of Compression and Torsional Shear

C. P. GRADY, *Douglas Aircraft Company*

Presented at the Meeting of the Los Angeles Branch of the I. Ae. S. September 30, 1938

THE purpose of this investigation was to obtain design information for structures of flat-bottom corrugations in combined compression and shear.

The method of presentation of the data is analogous to that used for data obtained at the California Institute of Technology on thin-walled cylinders in combined shear and axial loading. The tests were carried out by Bridget* under the direction of L. H. Donnell. The method of presentation is shown in Fig. 1.

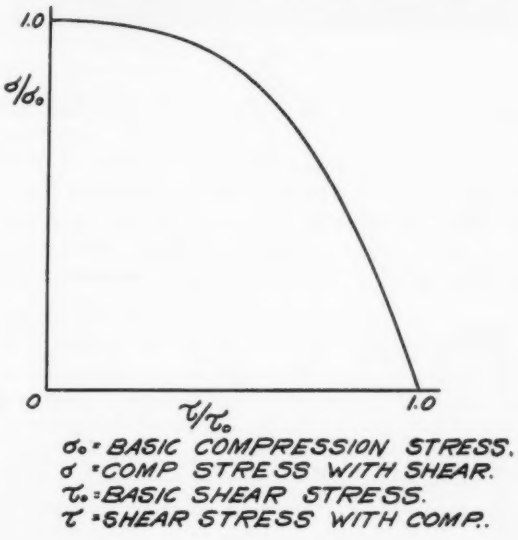


FIG. 1.

Specimens consisted of various combinations of thickness of 24ST Alclad flat plate and 24SRT Alclad corrugation of the form shown in Fig. 2. These panels were made up into three-sided caissons joined at the corners by curved plates of approximately the same R/t ratio as the corrugation but lower L/ρ to insure failure of the corrugations before failure of the cornices. (See Fig. 3.) These caissons were fastened to heavy steel base-plates with a solder-like bearing metal similar to babbitt to a depth of $^5/_{16}$ of an inch. One base plate was then bolted to the upper transom of the testing machine; the other, to a bearing ring plate on which three compression hydraulic jacks, seated on the lower transom, reacted. The two transoms were joined by flexible tension straps. Two hydraulic jacks, acting tangentially to the bearing ring plate, applied shear to the specimens. Shear in pounds per inch was calculated on the basis of effective included area of the caisson by the formula

$$\text{Torque} = 2AS$$

where A = effective area and S = shear in lb./in. Four specimens of each gage combination were made up, one to be tested in compression, one in shear, and two in combined loading.

P/D = 2.15
PITCH = 2.64 INCHES

FIG. 2.

Although the column allowables for corrugated panels had been determined before by two different kinds of tests, one with V-groove edge supports, and the other with clamped tube edge supports, it seemed advisable to establish ultimate values in compression for this particular type of test panel, as there was a slight disagreement between the V-groove and the tube-

FIG. 3.

* Bridget, F. J., *Thin-walled Cylinders*, A.S.M.E. Trans., August, 1934.

clamp tests. However, the ultimate stress points, based on $20t$ of effective sheet width, fell so close to the $20t$ ultimate curves of the other two tests as to permit their use in the calculation of the compression parameter in combined loading. This was only done, however, when the corrugation thickness of the combined loading caisson varied from that of the caisson in straight compression. A typical basic compression failure is shown on Fig. 4.

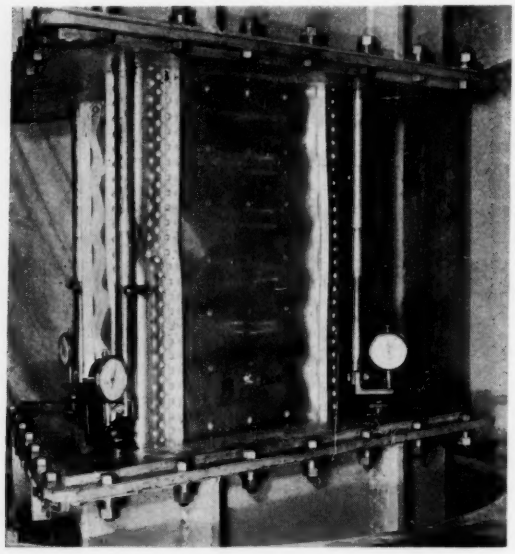


FIG. 4

The values for S_0 or ultimate shear per in. were then determined by test. A typical basic shear failure is shown on Fig. 5. Shear in pounds per inch run was chosen as the medium of presenting shear properties of corrugation because of the complications of attempting to determine an effective thickness of corrugated sheet. The variables involved in reducing shear load on a corrugated panel to shear stress included radius-thickness ratio, pitch-depth ratio, change in physical shape with deformation which changes the shear stiffness, and many others. These complications plus the fact that the corrugation shape is a standard at the Douglas Company, and that shear per inch is a convenient property form for designers to use were the factors for using shear per inch instead of shear stress.

Having established the basic ultimate values of compression and shear, the combined loading was taken up. It was naturally assumed that the corrugation combined loading curve would take a shape similar to that for thin-walled cylinders as previously mentioned Now since the A.S.T.M. 0.2 percent Y.P. was quite consistently around 60 percent for shear of caissons, it was considered safe to apply constant shear up to 60 percent of the ultimate and cause the specimens to fail in compression. For points farther down the curve, or above 60 percent shear, it was necessary to

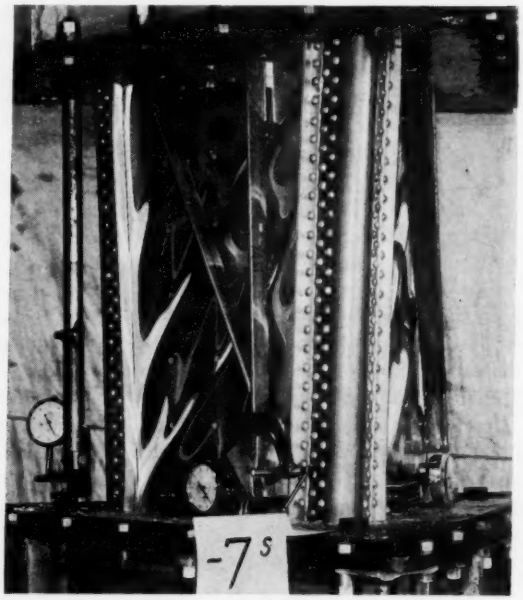


FIG. 5.

apply a constant compression and to cause the specimen to fail in shear. An inside envelope curve drawn under these points indicated the curve of Fig. 6. Points beyond the hundred percent shear mark were checked by additional caissons identical with the ones which gave those points. A caisson was then loaded along a 45° line, as shown on Fig. 6, by simultaneous shear

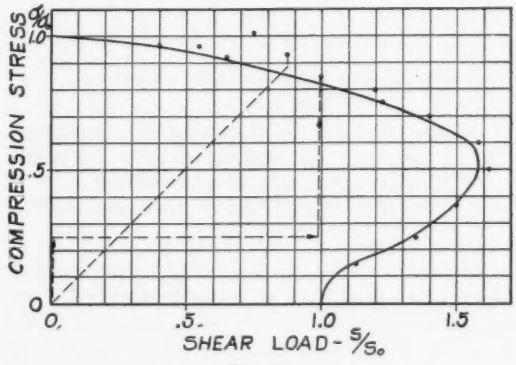


FIG. 6.

and compression loads of equal percentages; the point fell on the predetermined curve. Another caisson was loaded to about 25 percent of compression, then 100 percent of shear, and then carried to failure in compression; here again the point fell on the preliminary curve. Values for ultimate shears with less than twenty-five percent compression were then found, completing the curve and indicating that it comes into the shear parameter axis at ninety degrees. Fig. 7 shows a typical combined load failure.

A possible explanation for this unforeseen behavior in this: Each note of corrugation, round or flat is acting

as a flat-bottomed block; without compression it can tip quite easily, but with a compression load, a shear load must move against the compression load to a certain critical point of loading where it fails. This would allow a higher shear load to be applied with compression than without. Tension should also increase the allowable shear load over the ultimate in shear alone. In substantiation of the "block" theory, several observations were recorded: In shear alone the base-plates actually move apart, or in a tension direction, under a shear load. In combined loading when over 100 percent shear was applied, the compression was quickly removed; a large increase in shear deflection followed, but due to the principle of a hydraulic jack, the pressure fell off to a safe load. When the compression was reapplied, some of the shear deflection was taken up and a very small part of the shear load returned in proportion to the take-up of shear deflection. That the shear deflection did not return to its original position is probably due to plastic deformation or permanent set.

It must be obvious that the part of the curve beyond 100 per cent shear is useless for design purposes but must act as a hidden factor of safety.

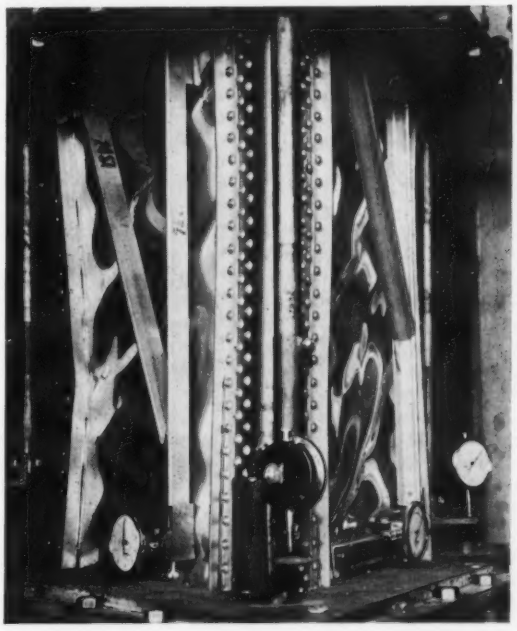


FIG. 7.

Book Reviews

Death Flies Low, by NEAL SHEPHERD; Constable and Company Ltd., London, 1938; 307 pages.

This book will meet every specification of a thriller, but in addition the locale is one of the new British aircraft shadow factories with research laboratories, wind tunnels, and a large experimental airdrome adjoining. Murder, sabotage, and espionage are all interwoven in the mystery. The Home Office, Scotland Yard, the Air Ministry, and local police all are involved in such a way that the jealousies, rivalries, and matters of official prestige come to the surface. As the publisher says, readers are shown a section of industry that is usually behind official curtains. No one who has any interest in aviation can start to read this book without getting to the last page before he puts it aside. Entirely apart from the interest it arouses by its plot, it gives a picture of the organization of a shadow factory, the working of supersonic wind tunnels, and the red tape that causes so much difficulty in all official life.

Air Stewardess, by NELLY GRAF. Gramercy Publishing Co., New York; $2.00.

Some engineers may read aviation fiction for the same reason that others read detective and mystery fiction. For the former, we reprint the publisher's digest of this romance:

"Grant Warton, wealthy playboy fell in love with his attractive nurse, Nerine Brill. When his society friends made her realize how impossible marriage with him would be, Nerine turned to the air for consolation.

"Flying above the clouds, viewing the world through a mist, she laughed at the earthbound. With a pilot like Ferd Sayre, Grant's friend, to guide the plane on which she served as hostess, Nerine could feel both safe and secure For Ferd had a square chin which bespoke determination, and the clear, eagle-like eye of a flier who looks through space to far horizons.

"Between them they foiled the machinations of a spy ring and narrowly skirted disaster in this thrilling, gripping, glamorous romance of the skyways."

Knight of the Air; by MALCOLM TAYLOR; Houghton Mifflin Company, Boston, 1938; 247 pages, $2.00

This is another story which is half biography and half fiction. A pilot acquires a modern airplane through an odd misadventure and, by advertising, obtains a job searching for a mysterious sapphire mine in Arabia. The flights from Palestine to locate and explore the mine bring the pilot and his associates many contacts with treacherous Arabs. The story has a well woven plot which takes the reader to interesting places, introduces him to types of middle East adventurers, and shows another use for airplanes in out of the way places.

NOTE

Several members have asked about the propriety of a technical journal publishing reviews of general aviation books. The reasons are as follows: Many engineers and other aeronautical specialists like to know of new books on aviation other than those in the technical fields so that they may have a broader field of reading. Often fiction gives information that is difficult to secure elsewhere. By printing short reviews of all types of aviation books, the library of the Institute is enlarged by books sent for review. Reviews of books on general aviation subjects are usually published at the end of technical articles which do not fill all of the page and therefore do not take space which would otherwise be used for technical material.

Institute Notes

International Congress of the Aeronautical Sciences

The Institute will sponsor an International Congress of the Aeronautical Sciences in New York on September 11 through 16, 1939, in connection with the New York World's Fair, 1939. The Council and Officers have invited governments, universities, and aeronautical organizations throughout the world to send delegates, as a tribute to the aeronautical scientific contributions of the Wright Brothers. Members of the Institute and other interested persons are urged to attend.

A banquet in honor of foreign guests will be held on Friday, September 15th, at which each nation and organization represented at the Congress will present a written tribute to the Wright Brothers. These will be bound and presented later to Mr. Orville Wright.

September 16 has been designated as "International Aviation Day" at the World's Fair and all delegates will be invited to attend. Columbia University has generously offered to provide rooms without charge in their residence halls for one hundred foreign delegates during the week of the Congress.

The technical sessions of the Congress will be devoted to contributions to aerodynamics, airplane design, structures, aircraft engines, meteorology, aircraft instruments, air transport, and other specialized fields of the aeronautical sciences.

Following are the committees in charge of the arrangements.

General Committee. J. C. Hunsaker, Chairman, Joseph S. Ames, H. H. Arnold, Lyman J. Briggs, A. B. Cook, J. H. Doolittle, Donald W. Douglas, W. F. Durand, C. L. Egtvedt, R. H. Fleet, Jack Frye, Robert E. Gross, J. H. Kindelberger, Glenn L. Martin, George J. Mead, Clark B. Millikan, Edward J. Noble, W. A. Patterson, George B. Pegram, F. W. Reichelderfer, E. V. Rickenbacker, Igor I. Sikorsky, Elmer A. Sperry, Jr., C. R. Smith.

Meetings Committee. Earl D. Osborn, Chairman, Luis de Florez, S. Paul Johnston, J. H. Kimball, Jerome Lederer, E. Burke Wilford.

Finance Committee. Leroy R. Grumman, Chairman, Vincent Bendix, Harry F. Guggenheim, F. B. Rentschler, J. T. Trippe, Guy W. Vaughan.

Program Committee. T. P. Wright, Chairman, A. M. Kuethe, Secretary, Hall L. Hibbard, Robert Insley, F. K. Kirsten, Alexander Klemin, A. E. Raymond, H. J. E. Reid, Philip B. Taylor, M. J. Thompson, John E. Younger.

Pacific Coast I. Ae. S. Annual Meeting

The Institute is holding a Pacific Coast Meeting in Los Angeles on June 15, 16, and 17, 1939. Dr. A. L. Klein of the California Institute of Technology has been appointed General Chairman. Three days of technical sessions will be held, at which contributions in Aerodynamics, Airplane Design, Structures, Meteorology, and other branches of the aeronautical sciences will be presented. It is hoped that this meeting will correspond to the Annual Meeting of the Institute in New York each year and will be held annually at some place on the Pacific Coast.

Major Gardner Honored

The Council of the Royal Aeronautical Society at its March meeting elected Major Lester D. Gardner, Secretary of the Institute, an Honorary Fellow. The award was made for Major Gardner's distinguished service to American aviation.

The Society, founded in 1866, is the oldest aeronautical organization in the world. In the seventy-three years of its existence it has elected only fifteen Honorary Fellows. Two other Honorary Fellows from the United States, previously elected, are Orville Wright and Dr. J. C. Hunsaker.

In acknowledging the notification, Major Gardner wrote the President and Council of the R. Ae. S. as follows: "I realize fully that a desire to recognize the cordial relations that have always existed between the Royal Aeronautical Society and its offspring, the Institute of the Aeronautical Sciences, was one of the principal reasons for your action."

Major Gardner has been actively engaged in aeronautical activities for twenty-five years. In 1916, he started *Aviation* magazine, which is now the oldest American aeronautical publication. He is a graduate of M.I.T., was President of the Aeronautical Chamber of Commerce in 1928, and was an officer in the Air Service in 1917–18. He is Secretary of the Daniel Guggenheim Medal Board.

Branches

The "Simultaneous Lectures" program scheduled for March 30th was entitled "Résumé of Annual Meeting Papers," by Prof. Alexander Klemin of New York University.

Boeing School of Aeronautics. At a meeting of the Student Branch on March 9th the two lectures, "Instruments for Blind Landings," by J. Lyman and L. Mosely and "A Terrain Clearance Indicator," by Lloyd Espenschied and R. C. Newhouse were read by Ray Stephan and Hadley Queen, respectively. These two papers comprised the "Simultaneous Lectures" program for February.

Carnegie Institute of Technology. The Student Branch held its second smoker of the year on March 3rd. The Espenschied-Newhouse and Lyman-Mosely lectures were read by Victor Saudek and O. B. Rosstead, respectively. About twenty students attended the meeting.

Casey Jones School of Aeronautics. At a meeting of the Student Branch, the Espenschied-Newhouse lecture was read by Nicholas Kintzer, after which the Lyman-Mosely paper was presented by William Horsefield. They were assisted by Armand Crossen and Sherman Zeliff. An interesting discussion followed the presentation. About thirty members and guests attended the meeting.

Los Angeles. A dinner and technical meeting of the Los Angeles Branch of the Institute of the Aeronautical Sciences was held in the Hollywood Athletic Club on February 28th. Mr. L. E. Root presented a paper entitled "Empennage Design with Single and Multiple Vertical Surfaces." J. R. Goldstein

presented a digest of the papers on "The Terrain Clearance Indicator" and "Instruments for Instrument Landing." Both lectures were followed by lively discussions. The meeting was attended by approximately 135 persons.

Massachusetts Institute of Technology. At a meeting of this Student Branch on March 8th, Prof. C. S. Draper presented the Espenschied-Newhouse and Lyman-Mosely lectures. This was supplemented with a short discussion of the Metcalf Blind Landing System which is being developed at M.I.T. The presentation was followed by an open discussion. About sixty students attended the meeting.

University of Michigan. The Student Branch held a meeting on January 20th at which R. W. Middlewood, Chief Engineer of Stinson Aircraft Division, gave an informal talk on "Aspects of Practical Engineering." F. Weston Palmer was elected Engineering Council Representative for the second semester.

At a meeting on February 16th, Prof. E. A. Stalker presented the Boeing 314 and Curtiss-Wright CW-20 lectures. These lectures comprised the second "Simultaneous Lectures" program.

San Francisco. A meeting of this Branch was held at the Pan-American Airways Base, Treasure Island, San Francisco Bay, on March 15th. The occasion for the meeting was the return of the Boeing Clipper from its initial round trip to Hong Kong. The members were shown through the plane as an introduction to the technical meeting which followed. Wellwood E. Beall, of the Boeing Aircraft Company, gave an interesting talk on the design characteristics of the Clipper and some of the incidents in the "shake-down" cruise. There followed a talk by F. J. Wiegand of the Wright Aeronautical Corporation on the development of the Wright R2600 engines and particularly on the cruising operation of the Chandler Groves carburetors.

Book Reviews

Air Fighter's Scrapbook, by SQUADRON LEADER IRA JONES; Nicholson and Watson, Ltd., London, 1938; 331 pages, 10s. 6d.

This book is aptly titled. It is by a British Ace with forty victories to his credit. He writes of his own experiences during the Great War with the R.A.F. in France and Russia, and after the armistice, about post-war flying in Iraq, Egypt, and in England. If this were all the book contained it would make interesting reading, but his evaluation of the greatest of English, French, and German pilots is from the pen of one who was in an excellent position to know them personally or to judge their work as enemies.

Squadron Leader Jones uses a clear and interesting style in presenting a miscellaneous mass of information. When the reader finishes the book he feels that he has made the intimate acquaintance of most of the leading airmen of our times.

Not only does the author tell of war pilots but all the great achievements of civil flying pass in review. It would be difficult to name any pilot who has achieved international fame, from Orville Wright to Howard Hughes, who is not mentioned.

The author's impressions of the work of the Royal Air Force, its beginning, its war efforts, and its development during the last twenty years add to the value of the biography.

Books of this type make the career of aviation appealing to the youth of today. Even though the kind of air fighting described may never occur again it perpetuates a tradition which will always be the glory of the air forces of the world.

The Airport Dilemma, prepared jointly by the American Society of Planning Officials, and the American Municipal Association; Public Administration Service, Chicago, 1938; 45 pages, $1.00.

For those who are interested in a comprehensive statement of the problems of airport policy—municipal, state, and federal—this pamphlet will inform them of the general situation in this country. It reviews the local and national factors in airport planning and financing. The growth of American Aviation is presented in comparatively condensed form. Inasmuch as the whole subject of airports is to receive the attention of the Civil Aeronautics Authority and a national policy will be inaugurated, this study will lay a foundation for a better understanding of the problems involved.

British Airways, by C. ST. J. SPRIGG; Thomas Nelson and Sons, Ltd., London, 1934; 150 pages.

As one of a series of books on discovery, this story of the development of British air lines is intended for boys and girls who are interested in aviation. It describes the working of the air service in the British Isles and along the great Empire air routes. The author is well qualified, as he is the editor of "Airways and Airports," the excellent British magazine on air transport. He takes his reader on a trip to the Cape and Singapore, and gives descriptions of the leading British transport aircraft, describes aerodromes and dispatching procedures. While not completely up to the minute on transoceanic service, the book gives the reader a well rounded picture of British commercial air progress.

Planes over Canada, by CAPTAIN A. H. SANDWELL; Thomas Nelson and Sons, Ltd., Toronto, 1938; 118 pages; 2s. 6d.

Canada has never received the credit she deserves for her many contributions to the advancement of aviation. This book should bring to the Dominion the appreciation of those who have overlooked many of the elements that have made the progress of aviation in Canada so important.

Starting with the work of Douglas McCurdy, who was undoubtedly the first British subject to fly within the Empire, Captain Sandwell proceeds to unfold the brilliant record of Canadian pilots during the War. The world is more or less acquainted with this phase, but even here, the extent of the participation is not too well known.

The prosaic work of carrying supplies and machinery by airplane into the interior of Canada and bringing minerals out has been regarded by many as an unorganized effort, and as a result, the pilots who have had to work off the lines of normal travel, have not received due credit. Without the least disparagement, they may be regarded as the "truck drivers" of aviation. But their "trucks" were a miscellaneous lot of aircraft which had to perform extremely difficult feats of flying, due to weather and terrain conditions. The forestry work, air mapping, fire fighting, and combating insect plagues, the work of prospectors and of the famous Royal Canadian Mounted Police, are all part of Canadian aviation history which should be acclaimed.

The book closes with a chapter about the Trans-Canada service which will be in full operation this summer.

Exchanges

The Institute exchanges the Journal with many other aeronautical periodicals. They are kept on file at the Skyport in Rockefeller Center, New York City, where members may read them. As readers of the Journal may wish to subscribe to some of them, a list of these periodicals with their addresses is published here. Information regarding subscription prices may be secured from the Secretary of the Institute.

Aero, Maneesikatu 2, Helsingfors, Finland.

Aero Digest, 515 Madison Ave., New York City.

Aeronautica Argentina, Velez Sarsfield 57, Cordoba, Argentina.

L'Aéronautique, 55 Quai des Grands-Augustins, Paris, France.

L'Aérophile, 7 Rue Sainte-Lazare, Paris, France.

The Aeroplane, 175 Piccadilly, London, W.1, England.

L'Aerotecnica, Via delle Coppelle 35, Rome, Italy.

Les Ailes, 77 Boulevard Malesherbes, Paris, France.

L'Air, 71, Champs Élysées, Paris, France.

Aircraft Engineering, 2 Bloomsbury Place, London, E.C.1, England.

Aircraft Production, Dorset House, Stamford Street, London, S.E.1, England.

Air Law Review, Washington Square East, New York City.

American Aviation, Earle Building, Washington, D. C.

Asas, Caixa Postal 1967, Rio de Janeiro, Brazil.

Astronautics, American Rocket Society, 31 West 86th Street, New York, N. Y.

Aviation, 330 West 42nd St., New York City.

L'Aviazione, Corso Umberto 504, Rome, Italy.

Bradshaw's International Air Guide, Surrey St., Strand, London, W.C.2, England.

Boletin de Aeronautica Civil, Calle Azcuenga 923, Buenos Aires, Argentina.

Bulletin du Service Technique de l'Aéronautique, 72 Chaussee de Waterloo, Rhode-Saint-Genese, Belgium.

Bulletin Technique du Bureau Veritas, 31 Rue Henri-Rochfort, Paris (17), France.

Canadian Aviation, Journal Building, Ottawa, Canada.

Contact, Fort Lee, N. J.

Deutsche Luftwacht, Schoeneberger Ufer 46, Berlin W35, Germany.

Der Deutsche Sportflieger, Peterssteinweg 19, Leipzig C1, Germany.

Les Fiches Aéronautiques, 6 Rue Galilee, Paris, France.

Flight, Dorset House, Stamford St., London, S.E.1, England.

Indian Aviation, P. O. Box 2361, Calcutta, India.

The Institute of Welding, 104 Victoria Street, London, S.W.1, England.

Interavia, 13, Corraterie, Geneva, Switzerland.

Journal of Air Law, Northwestern University, Chicago.

Journal of Research of the National Bureau of Standards, U. S. Govt. Printing Office, Washington, D. C.

Journal of the Royal Aeronautical Society, 7 Albemarle St., Piccadilly, London, W.1, England.

Journal of the Society of Automotive Engineers, 29 West 39th St., New York City.

L'Ala d'Italia, L'Aquilone, La Rivista di Diritto Aeronautico, La Rivista di Meteorologia Aeronautica, Le Vie dell'Aria, Vilea dell'Universita 4, Rome, Italy.

Letectvi, Celetna 13, Praha I, Czechoslovakia.

Luftfahrt-Forschung, Verlag Oldenbourg, Munich 1, Germany.

Die Luftreise, Lindenstr. 35, Berlin SW68, Germany.

Luftfahrt-Literaturschau, Z.W.B. bei der D.V.L., Berlin-Adlershof, Germany.

Model Airplane News, 551 Fifth Avenue, New York City.

Monthly Weather Review, U. S. Dept. of Agriculture, Washington, D. C.

Motor and Flying, 24 Bond St., Sydney, N. S. W., Australia.

National Aeronautics, Dupont Circle, Washington, D. C.

Official Aviation Guide, 608 S. Dearborn St., Chicago, Illinois.

The Pilot, Grand Central Air Terminal, Glendale, California.

Popular Aviation, 608 S. Dearborn St., Chicago, Illinois.

Publications Scientifiques et Techniques du Ministère de l'Air, 55 Quai des Grands-Augustins, Paris, France.

Revue de l'Armée de l'Air, 55 Quai des Grands-Augustins, Paris, France.

Revue du Ministère de l'Air, 71 Avenue des Champs Élysées, Paris (8), France.

Rivista Aeronautica, Ministero dell'Aeronautica, Rome, Italy.

The Royal Air Force Quarterly, Gale & Polden Ltd., 2 Amen Corner, London, E.C.4, England.

Schweizer Aero-Revue Suisse, Gubelhangstrasse 22, Zürich-Oerlikon, Switzerland.

Soaring, 1614 Delaware Ave., Wilmington, Del.

Southern Flight, Ledger Building, Fort Worth, Texas.

Sportsman Pilot, 515 Madison Ave., New York City.

Technical News Bulletin of the National Bureau of Standards, U. S. Govt. Printing Office, Washington, D. C.

Technika Lotnicza, Czerwonego Kryza 21/23 m.6, Warsaw, Poland.

Technika Vosdushnogo Flota, U1. Radio 16, Moscow 16, U. S. S. R.

La Technique Aéronautique, 2 Rue Blanche, Paris (9), France.

U. S. Air Services, Transportation Building, Washington, D. C.

Western Flying, 420 S. San Pedro St., Los Angeles, California.

Wirtschaft Technik Verkehr, Alte Jakobstr. 148/155, Berlin, SW68, Germany.

Zeitschrift für angewandte Mathematik und Mechanik, Kulmstr. 1, Dresden A24, Germany.

AERONAUTICAL REVIEWS

These brief reviews of recent articles on aviation subjects are published by the Army Air Corps for the information of its officers, and are printed here each month by permission of the Chief of the Air Corps

Aerodynamics

Research for Production. Equipment of the recently opened wind tunnel of Fairey Aviation Corporation, the mechanical and physical laboratories, and research being undertaken by the corporation. *Aircraft Engineering*, January, 1939, pages 28–29, 6 illus.

The Flow of Compressible Gas. B. V. Korvin-Kroukovsky. Relations are derived between velocity, density, and pressure in a flowing compressible gas on the fundamental mechanical principles of the conservation of matter, of momentum, and of energy. Results are checked by application to test data on discharge of superheated steam. Below certain (critical) pressure ratio the polyatomic gas behaves as a monoatomic one, indicating that energy transfer ceased between rotational and translational motions of molecules. This phenomenon occurs apparently only in accelerating flow, and change from acceleration to deceleration liberates the temporarily unavailable energy of rotation, and precipitates the sudden increase of pressure, known as "compression shock" in aerodynamics. *Journal Franklin Institute*, January, 1939, pages 99–110, 4 illus., 24 equations.

Science and Industry. Work at the National Physical laboratory on international standards, and relations with industry, and research in the physics, electricity, metrology, engineering, metallurgy, and aerodynamics departments and in the William Froude laboratory. Fuel research in preparation of coal for the market, hydrogenation, synthesis of hydrocarbons, production of lubricating oil, and use of pulverized fuel are also described. To be continued. Excerpts from Report for Year 1937–38 of British Department of Scientific and Industrial Research. *Engineer*, February 10, 1939, pages 180–182.

Aircraft Design

An Elementary Study of the Spin. J. H. Crowe. Review of existing knowledge on spinning phenomena. The flat spin; steady spin; importance of yawing couple; historical review of developments in the study of the spin during and after the war; geometry of the spin; five types of spin as far as sideslip is concerned; sideslip at the tail; balances of forces; effect of wing loading; inertia couples and an illustration of inertia effect; and pitching inertia couple. To be continued. *Aircraft Engineering*, February, 1939, pages 39–43, 7 illus., 9 equations.

The Flying Wing—Last Word in Aerodynamics. J. P. Eames. Apparent aerodynamic and structural advantages of the flying wing type of aircraft, and the practical approach to the ideal flying wing found in the Howard Hughes Racer and the "pterodactyl" or tailless airplane developed by Professor Hill in England. *Western Flying*, February, 1939, pages 13–14, 3 illus.

The Piloting Wind Vanes and High Automatic Stability. J. Mottez. The collaborator of M. Constantin has adapted the method of calculating the stability of an airplane, given by M. Schneider in a previous article, to the calculation of the wind vanes for automatic piloting integrated for the airplane, showing also the high automatic stability that can easily be obtained with the use of these wind vanes. *Les Ailes*, January 26, 1939, page 7, 4 illus., equations.

Principles of Rotary Aircraft. A. Klemin. Classification of rotary aircraft; autogiro or La Cierva rotor; Wilford gyroplane; performance of the autogiro compared with that of the airplane (comparison of parasite drags, comparison of machines built for very high speed, comparison with an airplane built for very slow speed, comparison of machines of moderate power suitable for private flying, and possibilities of improvement); autogiro, Wilford and Hafner direct controls; Wilford control in application to flapping blades; vibration; the de la Cierva jump take-off; Hafner towering take-off; Herrick Convertoplane; and the Pitcairn roadable autogiro. *Jour. Franklin Institute*, February, 1939, pages 219–249, 16 illus.

Selecting an Airscrew. A. G. von Baumhauer. Method described starts with the value of the airplane drag coefficient which the designer should know when developing his new type of airplane. The propeller is chosen for a certain condition of the airplane, say for cruising flight, for which the drag coefficient is estimated or known. A flight coefficient, Cy, which is a non-dimensional quantity, is developed. Curves show, as a function of flight coefficient, the efficiency, blade angle, relative pitch (blades with constant pitch and blades rotated), and diameter.

Method was developed because it was felt that the Cs method used in America, though very useful, was not quite satisfactory, as it disregards completely the qualities of the airplane. *Aircraft Engineering*, January, 1939, pages 9–12, 8 illus., 8 equations.

Stress Analysis and Structures

Engineering Aspects of Buckling. F. R. Shanley. Basic principles of buckling of simple columns and flat sheets, and how they may be used by the engineer. Discussion of free buckling includes: relation between buckling load and bending stiffness; end conditions; stress equations; plastic range for columns; buckling of flat, square, long, and wide plates; effect of aspect ratio; edge restraint; buckling under shear loads; and comparison of theory with test data.

Under the subject of restrained buckling, sheet-stiffener combination, plate girders of the shear-resistant type, and tension-field webs are considered. Applications of the buckling theories are taken up. Institute of the Aeronautical Sciences paper. *Aircraft Engineering*, January, 1939, pages 13–20, 30 illus., 16 equations.

Moments of Inertia of Annular Bodies. W. Samuels. Moment of inertia of ring bodies in general is investigated and a common theorem for ring inertias is presented. *Automotive Industries*, February 11, 1939, pages 166–169, 2 illus.

Prager Formulas Applied to Simple Bending. M. Précoul. In a manner similar to that applied to the box spar with equal flanges (given in the previous article) these formulas can be placed in the form of the relation of moment calculated to the modulus of resistance of the square multiplied by the ratio of work to compression. Formulas derived permit the determination, for a given square, of the thicknesses of the flanges capable of supporting a given moment. *L'Aérophile*, November, 1938, pages 253–254, 5 illus., 8 equations.

Aircraft

A Fighter Vogue. "France, Germany Italy, and Poland have already developed various types of two-seater twin-engined fighter, but so far no announcement has been made of a single-seater with two power plants, excepting, the experiment Fokker shown at Paris last year."

"In the multi-seater category the U.S. Army Air Corps already has the Bell pusher, and if, as it is reported, the Lockheed is a single-seater, it would appear that the U.S. Government is considering adopting bi-motor pursuit machines on a large scale." Brief note referring to press reports of the crash at Mitchel Field of a new Lockheed twin-engined fighter "reputed to have attained a speed of nearly 400 m.p.h." *Flight*, February 16, 1939, page 170.

The 1938 Paris Aero Show. Armament, controls, under carriages, flame dampers, and propellers as well a sinteresting points about the aircraft frames and engines exhibited are described. Drawings illustrate the design of the bomb cells on the P.Z.L. Los bomber, details of the split flap and split aileron on the starboard plane of the P.Z.L. Wyzel, unusual position on the pitot head on the trailing edge of the Koolhoven F.K.58, Fobo machine for riveting the insides of tubes, Bronzavia and G.A.L. exhaust systems, and aspects of the Brodeau system of construction. *Aicraft Engineering*, January, 1939, pages 3–8, 15 illus.

More Variable Wings. Modified version of the original Makhonine airplane, which was built in France some years ago to try out theories on wings of variable area, has been brought out again after modifications at Villacoublay Arsenal. It now has a 1000-hp. Gnôme Rhône 14N radial engine, retractable undercarriage and closed cockpit. Wing area extended is 355 sq. ft. and retracted 194 sq. ft., wing-area variation being done hydraulically. Wing loading is 31.2 lb./sq. ft. in extended position and 57 lb./sq. ft. in the retracted. Maximum speed is estimated as 323 m.p.h. and range 3728 miles. Short note. *Aeroplane*, February 8, 1939, page 186.

CZECHOSLOVAKIA

Aero A-300 Bomber. A. Frachet. Three-seater bomber monoplane of wood and steel-tube construction can compete with all-metal airplanes of the same tonnage. With two Bristol Mercury IX 830-hp. engines, the bomber has a speed of 470 km./hr. at 5500 meters and an absolute ceiling of 8300 meters. It may also be used for a variety of missions. As a bomber it will carry normally 500 kg. of projectiles with a range of 900 km. and, overloaded, gasoline for a range of 1400 to 2000 km. Long description of construction, aramament, characteristics, performance. *Les Ailes*, January 26, 1939, page 9, 3 illus., 1 table.

FRANCE

Eleven Tons at More than 500 Km./Hr. This is the performance which has been officially reached by the LeO-45 bomber (two Gnôme Rhône 14-N.20/21 engines giving 2060 hp.). Photographs showing new Mercier cowlings on the engine. *Les Ailes*, February 9, 1939, page 1, 4 illus.

A Novel "Elytroplan" Starts Its Tests. Rouge'-Bouffort Elytroplan is a tailless airplane, wing tips of which are fitted with two vertical stabilizers and rudders serving also as aerodynamic brakes. Fuselage is very short and has a 38-hp. Polymecanique engine at the front and at the rear another rudder. A horizontal surface, the "elytre" is mounted on a tripod above the fuselage and acts as an elevator. Few details and photographs. *Les Ailes*, February 9, 1939, page 12, 2 illus.

Aircraft in Test. Brief references only to the following military aircraft in test: January 1st issue—LeO.45 bomber (two Gnôme-Rhône 14-N.20/21 engines giving 2060 hp.) officially attained a speed of 500 km./hr. at 5100 meters, and with normal armament and at a total weight of more than 11 tons. Dewoitine D-520 prototype (Hispano-Suiza 12-Y 910-hp. engine cannon) has a speed around 525 km./hr. at 4420 meters and should exceed 560 km./hr. with the 1000-hp. Hispano engine. Bloch 135 prototype high-speed bomber (four Gnôme-Rhône M-14 engines) weighs 5850 kg. empty, will carry a load of more than 4000 kg. (900 to 1400 kg. of bombs), has a range of 2000 km. at 85 to 100 percent power, and should climb to 5000 meters in 9 min., its maximum speed at that altitude being around 525 km./hr. Seversky 2-PA-LB two-seater pursuit (Pratt-Whitney Twin Wasp 1100 hp. engine) is being tested.

January 19th issue—Bloch 500 T.3 three-seater army-cooperation airplane (two Lorraine Algol 300-hp. engines) constructed of wood. Tests of the Potez 63 (two Pratt-Whitney Twin Wasp engines) were interrupted to change one of its engines). Bloch 174 A-3 B-3 airplane (two Gnôme Rhône 14-N.20/21 engines of 2060 hp.) has a surface of 44 sq. meters, weighs empty around 4500 kg. and loaded 6200 to 6400 kg., and has a range around 1400 to 1800 km. Koolhoven F.K.58 single-seater.

February 2nd issue—Bloch 174 (two Gnome Rhone 14-N.20/21 engines giving 2060 hp.) three-seater long-range reconnaissance and light bomber making 500/520 km./hr. Amiot 350/351 high-speed bomber (two Gnôme Rhône engines of 1030 hp., new cowlings, and double fins on the tail planes) should attain around 510 km./hr. Morane-Saulnier 450 prototype pursuit (Hispano-Suiza 12-Y 1000-hp. engine) should exceed 550 km./hr. Another airplane of this type calculated with a new profile for the wing should attain 600 km./hr. Dewoitine D-520 of the new program of pursuits (Hispano Suiza 12 Ycrs engine) attained a speed of 521 km./hr. at 4800 meters. Modifications and improvements should add 10 km. and raise the altitude by 500 meters.

February 9th issue—New version of the Bréguet 691, equipped as a two-seater fighter (two engines of 1000 hp.) has exceeded 550 km./hr., has excellent maneuverability and should have an important range. Another 691 collapsed in rolling on the ground, due to rupture of the landing gear. Bloch 152 single-seater combat (Gnôme Rhône 14-N.25 engine). C.A.O. 200 single-seater pursuit (Hispano-Suiza 12-Y.31 860-hp. engine) should reach 550 km./hr. at 4000 meters. Sversky 2P.A.L. two-seater pursuit has been pronounced as unstable and of a mediocre centering by the French test pilots of the C.E.M.A. (official speed 485 km./hr., that announced for the single-seater, in the U.S. services, being 520 km./hr.). Amiot 351 has two Gnôme Rhône 15-N.20/21 engines, but will also be tested with two Rolls-Royce Merlin 10 engines. Loire-Nieuport 40 dive bomber supplied with aerodynamic brakes has been ordered in series by the Navy. Galtier 30 single-seater pursuit of wood (Hispano-Suiza 12-X 690-hp. engine) has received a new covering. Curtiss P-36 tests.

February 16th issue—Bloch 135 four-engine bomber. Dewoitine D-520 single-seater pursuit (Hispano-Suiza 12Y 900-hp. engine cannon) attained a speed of more than 800 km./hr. in a dive test. Bloch 203 (two Clerget 14-F-00 heavy-oil engines). Morane-Saulnier 430 two-seater trainer in piloting modern airplanes. Bloch 134 bomber derived from airplanes constructed in series (two Gnôme Rhône N-50 engines with two-speed supercharger, and each developing 1400 hp. on the ground). *Les Ailes*, January 1, 19, February 2, 9, and 16, 1939, pages 7, 9, 8–9, 7, 9.

GERMANY

Going Up. Focke helicopter is said to have beaten its own altitude record of 8000 ft. by climbing to somewhere between 11,000 ft. and 12,000 ft. Brief reference only. *Aeroplane*, February 15, 1939, page 195. *Les Ailes*, February 9, 1939, page 4.

Fieseler Fi-99 Jung Tiger Two-Seater Sport Airplane. Fieseler Jung Iiger low-wing monoplane. Hirth HM-506-A 160-hp. engine. Maximum speed 240 km./hr. Cruising speed 205 km./hr. Range 1000 km. Short description, characteristics, and performances. *L'Aérophile*, November, 1938, page 248, 1 illus., 1 table.

GREAT BRITAIN

Delaying the Stall. Aims of the design of the Willoughby Delta 8, flying scale model of a large transport, are to provide an airform which should be, for all practical purposes, free from the vice of stalling and which should also approach the all-wing ideal and carry its load well-distributed spanwise so as to make for low structural weight. By use of a symmetrical section for wing tips of the front wing, it has been found possible to delay stalling of the tips until quite large angles of incidence are reached.

Known as the type Delta 9, the larger machine will have a gross weight of 38,000 lb. and will have accommodations for 18 passengers in each of the two side wings. Long description. *Flight*, January 9, 1939, pages 143–146, 8 illus.

New Two-Seater Fighters. Boulton and Paul Defiant two-seater all-metal low-wing monoplane fighter with which R.A.F. squadrons will shortly be equipped, has a power-driven gun turret faired as completely as possible compatible with good field of fire. Under the assumption that the engine is a Merlin II, speed of the Defiant is estimated as around 300 m.p.h. considering drag of turret and fact that dimensions are little larger than those of the Hurricane. It is thought that the Defiant will be used for attacking enemy bomber formations, probably by flying slightly ahead of and below the raiders. Wing span is 39 ft. 6 in.

Hawker Hotspur two-seater fighter (Rolls Royce Merlin engine) is comparatively small (span 40 ft. 6 in.) and has a turret of unusual barrel-shaped design. New ejector-type exhausts and DeHavilland three-bladed variable-pitch propellers are used on both fighters. Description of Defiant but only a few details of the Hotspur. Photographs of both included. *Flight*, February 9, 1939, page 139, 2 illus. Photographs only of the Defiant. *Aeroplane*, February 8, 1939, page 155, 2 illus.

Spitfires for the Squadrons. Test program to which every production Spitfire is subjected after it is trundled out of the hangar. *Flight*, February 9, 1939, pages 134a–134c, 8 illus.

The DeHavilland Flamingo. DeHavilland D.H.95 Flamingo all-metal 15–23 seater medium-capacity transport. Wing loading is comparatively low (26.6 lb./sq. ft.) and this is combined with low weight per horsepower. Both of these characteristics coupled with the use of Handley-Page slotted flaps make for good take-off and climb.

Reasons for putting the wing on top of the fuselage, advantages of large propellers running at half engine speed, airplane structure, and results of preliminary trials are discussed and detailed specifications and performances are given. Cutaway drawing shows location of equipment and structural parts are illustrated in drawings. Two Bristol Perseus XIIc 890-hp. engines. Maximum speed 243 m.p.h. at 7500 ft. Maximum cruising speed 227 m.p.h. at 5000 ft. Take-off 250 yd. Landing 275 yd. *Aeroplane*, February 15, 1939, pages 214–218, 16 illus. Long description with drawings of structural details, and characteristics and performances. Second article describes the control and instrument layouts and flying characteristics. *Flight*, February 16, 1939, pages 151–158, 168–169, 18 illus., 1 table.

The Percival-Henshaw-Cross Mew Gull. Improvements made to A. Henshaw's Mew Gull airplane by J. Cross of Essex Aero, Ltd. are described in detail. Mew Gull was the winner's machine in the King's Cup Race and after remodeling was flown to South Africa and back. Performance of the airplane which was tried out by the author is discussed. Cutaway drawing of the cowling shows location of equipment. Demec navigation light made retractable by Esso Aero and other equipment are illustrated in drawings. *Aeroplane*, February 22, 1939, pages 249–250, 5 illus. Spectacular flight from London to Cape Town and back was recently made by A. Henshaw in 106½ hours in a tiny single-seater racing airplane, a Mew Gull (Gipsy Six series II engine). Account of flight and details of improvement and equipment of the airplane. *Flight*, February 16, 1939, pages 159–160, 2 illus. *Aeroplane*, February 15, 1939, pages 221–222, 1 illus.

The Sunderland Flying Boats of the Royal Air Force. The Sunderland is said to be the "largest flying boat in service with any Air Force in the World today." It is an all-metal boat seaplane with a cantilever monoplane wing and is driven by four Pegasus XXII aircooled radials providing a total of 4040 hp. for take off and maximum of 3360 hp. at 6250 ft. Boat is normally loaded to 45,000 lb. which on a wing area of just under 1500 sq. ft. works out at a wing loading of 30 lb./sq. ft. Maximum speed (at 45,700 lb.) 210 m.p.h. at 6250 ft. Maximum range 2500 sea miles. Long detailed description, characteristics, performance, armament, cutaway drawing showing location of equipment, and drawings of details of the wing structure. *Aeroplane*, January 25, 1939, pages 115–117, 106–107, 23 illus.

Upping the Lift. Reports by independent pilots on the Westland Lysander confirm early reports of the extraordinary good behavior of this fully slotted and flapped airplane at low speeds and show that earlier figures for maximum lift coefficient were unduly conservative. With motor running, height can be maintained at the exceptionally low indicated airspeed of 49½ m.p.h. Turns with up to 30° of bank can be made on the glide quite easily with stick pulled hard back, and good tu ns can be made on either ailerons or rudder alone while cruising. Short note. *Aeroplane*, February 8, 1939, page 186.

HOLLAND

Koolhoven F.K.58. Koolhoven F.K.58 high-speed single-seater pursuit is equipped with either a Mercury VIII 830-hp. or a Hispano-Suiza 14 A.A.10 1080-hp. engine. Long description of construction, equipment, armament, and the characteristics and performance with both engines. With the Hispano engine top speed is 480 km./hr. at 4500 meters, cruising speed 430 km./hr. and range 850 km. *L'Aérophile*, November, 1938, pages 245–246, 2 illus., 1 table.

ITALY

Macchi C-99 Flying Boat. Macchi C-99 bimotored military flying boat derived from the record breaking Macchi C-94. Two Isotta Fraschini Asso XI R.C.-15 engines mounted above the wing give a total of 1672 hp. Maximum speed 272 km./hr. Short description. *L'Aérophile*, November, 1938, page 246, 1 illus., 1 table.

Stefani S.S.2 "Canard." Stefani S.S.2 "Canard" is powered by a 16-hp. two-cylinder opposed engine. On the semi-wings are placed two rudders which also operate as aerodynamic brakes. A fixed horizontal plane and elevator are located at the tail of the fuselage. Elevator is formed by a flap forming a slot with the fixed plane. Top speed 102 km./hr. Short description, characteristics and performances. An S.S.3 experimental combat plane is being developed from the S.S.2. *L'Aérophile*, November, 1938, page 247, 1 illus., 1 table.

Savoia-Marchetti S-75 transport airplane (three Alfa-Romeo 126-R.C. 34 engines giving 2250 hp.) was flown 2000 km. at 330 km./hr. with a useful load of 10,000 kg. Transport was piloted by N. Prota and G. Bertocco who were accompanied by a mechanic and passenger. This perforamnce is considered remarkable as the airplane carried a load greater than its weight empty which is normally 10 tons. Brief reference. *Les Ailes*, January 26, 1939, page 8, 1 illus.

Nardi F.N.-130 Touring Airplane. A. Frachet. Nardi F.N.-130 is a monoplane of mixed wood and steel-tube construction which transports four people over 1400 km. when powered with a 180-hp. engine (Fiat A-70/S 6-cylinder radial). Maximum speed 300 km./hr. Climb to 4000 meters, 17 min. Ceiling 6000 meters. Long description. *Les Ailes*, February 16, 1939, page 9, 3 illus., 1 table.

U. S. A.

American Planes and Engines. Photographs, line drawings, and complete specifications are given for 60 military aircraft, 33 airplanes of 6 or more seats, 43 airplanes of 3 to 5 seats, and 57 airplanes of one and two seats. *Aviation*, February, 1939, pages 32–53, many illus. and tables.

Curtiss-Wright Shows Off New C-W 21 Interceptor—First Minute Climb Reported Best on Record. Curtiss-Wright CW-21 "Interceptor" (Wright R 1820-G5 Cyclone 1000-hp. engine) is said to be the fastest climbing aircraft that has ever been flown, doing a first-minute full-throttle climb of more than 5280 ft./min. Maximum speed over 300 m.p.h. at 17,000 ft. and cruising speed over 270 m.p.h. Cruising range 592 miles at 600 b.hp. Long description of design and construction with mention of armament supplied. *Aviation*, February, 1939, pages 84–85, 4 illus.

Kelsey Just Loafed Along at 7 Miles a Minute. Comments on Lt. B. S. Kelsey's transcontinental flight in the Lockheed XP-38. *U.S. Air Services*, March, 1939, page 12, 1 illus.

The New Fairchild. New Fairchild 1939 Model "24" airplane. Improvements are described with photographs of the new tail wheel "which is steerable and full-swiveling after it passes the 50° steering arc," and landing gear which features a hydraulic brake and shorter stroke oleo. *Western Flying*, February, 1939, page 21, 3 illus.

Testing the Stratoliner. Boeing Stratoliner 33-passenger transport airplane "first in the world designed for passenger operation on the 'upper level' of the substratosphere." Description of airplane and reference to tests. *Western Flying*, February, 1939, page 20, 2 illus.

An American Auxiliary. North American B.T.9B trainer Harvard (550-hp. Pratt and Whitney Wasp engine) built for the Royal Air Force. Long description praising the undercarriage but calling the spin a bit vicious and fast. *Aeroplane*, January 25, 1939, pages 118–119, 3 illus.

Built-In Slots. Explanation of the built-in slots used on the five-seater Clark F.46 airplane, as given to the editor by Colonel V. E. Clark on his visit to London. Details of the "New Little Douglas" D.C.-5 are also given. *Aeroplane*, February 1, 1939, pages 135–136.

Curtiss-Wright CW-21. Showing a maximum initial rate of climb of better than 5000 ft./min., a top speed in excess of 300 m.p.h. and a cruising speed of 275 m.p.h., the Curtiss-Wright CW-21 interceptor fighter has completed flight tests at Robertson, Missouri. The design has an ultimate high angle of attack load factor of 10 as calculated by standard U.S. Army Air Corps methods. Climbing at the rate of a mile a minute, at an incredible angle, the C.W.-21 combines features of a pursuit and interceptor fighter. Power is supplied by a 1000-hp. Wright Cyclone engine rated at 750 hp. at 15,200 ft., and 850 hp. at 6000 ft. Long description, design, construction, armament, characteristics, performance. *Aero Digest*, February, 1939, pages 51–52, 6 illus.

The Fairchild "24" for 1939. Oleo strut on landing gear has been redesigned by enlarging cylinder and piston to permit a shorter stroke and less lateral spread on landing. Hydraulic brakes replacing the mechanical, and full-swivelling steerable tail wheel are used. Cabin is larger and has more attractive instrument panel and recontoured seats. The 145-hp. Warner Super Scarab, or the 165-hp. Ranger engine is used. Cruising speed (Warner engine) 123 m.p.h.; (Ranger) 128 m.p.h. Long description. *Aero Digest*, February, 1939, pages 60, 64, 5 illus.

Flight Tests of the Boeing 307 Stratoliner. All-metal low-wing monoplane has a semimonocoque fuselage, wings of typical Boeing combination truss and stressed-skin type, wing flaps electrically operated, and both landing gear and tail wheel retractable by electric means. Fuel tanks in the wings have a capacity of 1700 gal. and engine nacelles are of a new semimonocoque type featuring quick detachability of power plants. Four 1000-hp. Wright Cyclone GR1820-G102 engines are used. Description of airplane, and functional and proof load tests, and mention of special test instruments being installed on panels in the navigator's compartment immediately aft of the control room for the flight test program ahead. *Aero Digest*, February, 1939, pages 67–68, 4 illus.

Aircraft Alighting Gear

The Electric Joint. Retractable landing gear with electric control, developed by Air Equipment, is mounted in series on the Amiot 350/35 bimotored airplane. Complete landing-gear arrangement comprising the landing shock absorbers, wheel with its brakes, "electric joint," descending shock absorbers and fastenings are fixed on the airplane by only four bolts. Two hydro-pneumatic shock absorbers are connected by one axis and a crossbar forms a frame which carries the cast magnesium wheel.

"Electric joint" is placed at the point of articulation of the two parts of the rear leg of the undercarriage. The motor and its reduction gear are rigidly fixed to the upper part. The part controlled by the reduction gear is attached to the lower part of the rear leg and makes it turn with respect to the upper part. Description. *Les Ailes*, February 16, 1939, page 8, 2 illus.

For Happier Landings. Various types of landing gear on American aircraft are shown in photographs. *Aviation*, February, 1939, pages 28–29, 12 illus.

Aircraft Manufacture

Machine Production of Airplane Parts. D. I. Carroll. Machine tool methods used in the Vultee Aircraft Division of Aviation Manufacturing Corporation for manufacturing a wide variety of aircraft parts and to speed final assembly. *American Machinist*, February 8, 1939, pages 40–43, 7 illus.

A Polish Engineer on Production. Z. Cyma. Problem of producing airplanes in series. Output and price, cooperation between designer and engineer, and mechanical production methods are discussed. *Aircraft Engineering*, January, 1939, pages 25, 31.

Production Engineering at the Vultee Plant. Production Department bases its operations on a master schedule for each model. System of production control which can handle an unlimited number of projects simultaneously and which was expressly developed for this purpose, as well as the V-12 attack bomber and its armament are described. *Aero Digest*, February, 1939, pages 71-72, 74, 11 illus.

Moulded Structures. M. Langley. In the proposed method the internal shape of component fuselage, wing section, control surface or gasoline tank would be cast in concrete. This mould may have grooves on its surface corresponding to positions of stiffening ribs or webs, and may be made in fitted sections to be withdrawn from the finished unit in parts. Whole surface may be metallized. Thin wood or fabric impregnated with synthetic resinoid in the unpolymerized form, is wrapped around the concrete mold, a reinforcing fabric bandage holding the wood in position. Metal bushes and fittings may be incorporated where they are required and the whole covered with a high-melting-point wax.

Mould is put into a container which is filled up with some fluid. Thermostatically controlled electric heater in the fluid causes the temperature to rise and fluid expanding creates pressure. Completely new methods of construction are considered possible. Method described and illustrated. *Aeroplane*, February 8, 1939, pages 185–186, 4 illus.

Machines for Aircraft. D. I. Carroll. Applications of improved machines, production jigs, and special units by means of which profiling and forming operations and assembling of parts are speeded up in the Vultee plant. *American Machinist*, February 22, 1939, pages 76–79, 4 illus.

Series Construction of the Hurricane I. Methods of production used by the Hawker Aircraft, Ltd., in the production of the Hurricane I are described, including: work of the planning and progress departments; production scheme; spar shop; press shop; machine shop; fuselage primary erection; rib shop; main plane, center section, and auxiliary surface erection; covering and doping shops; wood shop; sheet-metal work; cutting and shaping shop; cowling shop; tank shop; final assembly; fuselage assembly; covering and doping; final assembly; and flight shed. *Aircraft Engineering*, February, 1939, pages 61–71, 33 illus.

Aircraft Accidents

A Case for Publication. According to evidence, a North American trainer for the R.A.F. began to spin at about 3000 ft. and then the pilot released the tail parachute with which machines are fitted when they are going to do spinning tests. The spin stopped, the parachute came off, and the machine then got into another spin and crashed. "Without slots these machines drop a wing and spin badly if stalled, and they stall at quite a high speed. That is why the U.S. Army Air Corps insisted that slots must be fitted. . . . The points to be cleared up about this particular crash is whether the N.A.A., with or without slots, as may have been, is particularly liable to get into a flat spin in particular conditions, or whether this particular aeroplane was loaded to produce an artificial spin." Brief editorial. *Aeroplane*, February 22, 1939, page 227. *Flight*, February 23, 1939, page 185.

Air Transportation

Review of Practical Tests of Commercial Aerial Exploration over the North Atlantic. List of test flights made by France, Germany, and England in preparation to opening transatlantic services. *L'Aérophile*, December, 1939, page 271.

Pan American Ready to Start Atlantic Passenger Line. Pan American plans for initial flights over the southern route via Azores, granting of French permit, and Imperial Airways transatlantic plans are discussed. It is understood that 16 applications are pending for permits to operate transatlantic airlines, two or three American applicants being regarded seriously. *Aero Digest*, February, 1939, pages 17–18, 35.

Airships

The New Zeppelin LZ-130. New Zeppelin is powered by four Daimler Benz 800 to 850-hp. Diesels and is divided into 16 compartments, each one of which carries an envelope for gas. Diameter 41.20 meters. Length 245 meters. Theoretical maximum speed 135 km./hr. Total lifting force 200-000 kg. Description, characteristics, performance. *L'Aérophile*, November, 1938, pages 248–249, 5 illus.

Electrical Installation of the Airship LZ-130. E. Hilligardt. Electrical installation is described insofar as it differs from that of the Hindenburg airship. Advantages of the use of alternating instead of direct current are enumerated, and it is demonstrated that by this change for the same size of installation, a saving of 18 percent of the weight could be obtained. Use of exhaust and cooling-water heat of the 40-hp. Diesel machines for cooking purposes and hot-water supply brought about a reduction of the electric power by 7.2 kw. and a weight saving of 300 kg.

Rudder installation is described in more detail and it is shown how, in the case of alternating current, an additional control range of the turning speed of the rudders is possible. *E.T.Z.*, February 16, 1939, pages 185–189, 8 illus.

Particulars about Airship LZ-130. Construction, dimensions, engines, performance, and passengers' rooms. *Airship*, January–March, 1939, pages 45–46, 1 illus.

Why No Blimps? Commander T. G. W. Settle. Performance of the blimp compared with other coastal types of craft, and suggestions for providing blimps during the next five years. *U.S. Naval Inst. Proc.*, February, 1939, pages 238–248, 6 illus.

The Zeppelin Crisis. H. Eckener. Present crisis in the zeppelin program. Comparison of helium and hydrogen inflated airships in regard to weight; yield from the ballast water producer for determining at what weight the airship must be maintained during the greater part of the trip; conditions for the return trip from America to Germany; loss of helium through the valves in a descent and through diffusion; and gas losses during the process of purifying the gas. *Airship*, January–March, 1939, pages 43–44, 47, 50, 1 illus.

Propellers

Recent Airscrew Research. W. G. A. Perring. Experimental work on propellers which has been carried out in the 24-ft. wind tunnel of the Royal Aircraft Establishment. Tunnel, propeller rig and equipment used for measurement of thrust, torque, engine speed, wind speed, and blade twist are described and illustrated. Scope of tests, typical test results, and method employed for analysis of data are considered. General propeller problem, design considerations, and the take-off problem are discussed in detail. *Aircraft Engineering*, February, 1939, pages 47–54, 21 illus., many equations.

Improving Aircraft Propellers by Surface Rolling. G. Sachs. Out of a number of propellers used in competition with aluminum an alarming fraction of magnesium propellers broke after short service periods. Such failures are considered. Results of small-scale fatigue tests to find out the main factors reducing the fatigue strength of magnesium alloys are discussed.

Surface rolling, an effective method developed to improve fatigue strength of parts subjected to erosive action, and its practical application in manufacturing propellers are described. Results are given for full-scale experiments with propellers made by this method and tested on equipment designed for determining vibration characteristics of engines and propellers. It was found that the higher the rolling pressure, the higher the fatigue strength, and that surface damages had no influence. An intermediate layer of fiber of about 1/8 -in. thickness increased fatigue strength of untreated test pieces by about 10 to 50 percent of standard value, and an intermediate layer of fiber increased fatigue strength of material, surface rolled under manufacturing conditions to about 85 percent. Internal stresses introduced by surface rolling are explained. *Metals & Alloys*, January, 1939, pages 19–23, 9 illus.

Miscellaneous

1939 World Automotive Engineering Congress of the Society of Automotive Engineers. Tentative technical program of the New York, Indianapolis, Detroit, and San Francisco meetings planned for the period May 22–June 8.—*S.A.E. Jour., Sup.*, February, 1939.

600 Planes at Miami Races. Account of light plane cavalcade in which 500 light planes took part, and results of races. Short note. *Aero Digest*, February, 1939, pages 16–17, 4 illus. *U.S. Air Services*, February, 1939, page 26.

Aeronautics Day by Day—September 1st to November 30th, 1938. Aeronautical events in this period are listed. *L'Aéronautique*, January, 1939, pages 46–48, 3 illus.

The National Aviation Forum in Washington. J. S. Edgerton. Highlights in key papers and addresses at the Forum. *U.S. Air Services*, March, 1939, pages 19–20, 35.

Research and Production. "One cannot read this annual report of the N.A.C.A. without coming to the conclusion that now as in the past the tremendous progress made by American aircraft constructors during the last few years is and has been due in a very large measure to the lead given by American research. Not only does American research equipment seem to be ahead of ours in a great many directions, but the whole outlook on the subject is wider, more 'practical' and somehow less 'academic' than in this country. And the reports and notes of the N.A.C.A. are issued quickly—and at a price which everyone can afford." Short editorial. *Flight*, February 16, 1939, page 150.

Overflow Crowds Fill Sessions at 1939 Annual Meeting. Review of sessions of the Society's annual meeting with abstracts of papers and discussions. *S.A.E. Jour.*, February, 1939, pages 13–16, 25–37.

Acoustics

Noise and Noise Measurement. D. Silverman. Bibliography on the acoustical basis of noise measurement, physiological effects of noise, instruments for measurement and analysis of noise, electrical instruments applied to the study of noise, application of noise measuring instruments, and methods of correction of undesirable noise conditions. *Electronics*, February, 1939, page 34.

Aircraft Instruments and Navigation

Air-Track Compass. New type of earth inductor compass suitable for aeronautical and mariner use is said to have almost instantaneous recovery to the correct reading after pitching, rolling, and banking. Few details. *Aero Digest*, February, 1938, page 81.

The Gadgets of the DC-4. Photograph and drawing of the pilot's compartment of the Douglas DC-4 airplane showing location of equipment. *Western Flying*, October, 1938, page 24, 2 illus.

Kollsman's New Compass Has Pointer Indication. New magnetic compass, called a "direction indicator." Dial is graduated to 2° and corresponds to the compass rose. Pointer shows direction of heading of the airplane in relation to the magnetic North. Few details. *Aero Digest*, February, 1939, page 81, 1 illus. *U.S. Air Services*, February, 1939, page 34, 1 illus.

New Robot Pilot for Planes Warns If Instrument Errs. New "tell-tale" robot, developed by the St. Louis Division of Curtiss-Wright Corporation, can flash on 90 lights to announce as many kinds of "trouble" before it happens. Ten selector switches enable the pilot to set the system for each of the main operations concerned in flying an airliner. Few details. *Science News Letter*, February 18, 1939, page 100.

Pioneer Panel-Mounted Magnetic Compass. Magnetic compass, somewhat similar to Air Corps Model B-17, but designed especially for use on commercial and private aircraft, and the Autosyn wheel and flap indicator are described. Latter has three small flags to represent wheels on the airplane. When wheels are down but not locked, flags move up and show red warning markers. If power is turned off, all three wheels drop out of sight. Wing and flap are indicated at the bottom of the dial, flap acting as a pointer to indicate flap position. *Aero Digest*, February, 1939, page 78, 1 illus. Description of Autosyn indicator. *U.S. Air Services*, February, 1939, page 32, 1 illus.

What Can the Air Sextant Do? F. Chichester. Advantages and use of the air sextant in navigation during wartime and in transatlantic and Polar flights. *Aeroplane*, February 1, 1939, page 142.

Aircraft Instruments and Accessories. Photographs of aircraft instruments and other equipment, and a directory of manufacturers of such equipment. *Aviation*, February, 1939, pages 62–63, 68, 71, 13 illus.

For Instrument Driving. Rotax B-2A "Eclipse" positively-lubricated sliding-vane pump is engine driven and runs at approximately 1 1/2 times engine speed. Pump provides sufficient suction for operation of a turn-and-

bank indicator, a directional gyro and an artificial horizon. By means of the Rotax Eclipse Type AV-1 regulating valve excessive suction is automatically countered by admission of air at a predetermined pressure. For dual installations a check valve Type NFBJ automatically cuts out the appropriate unit should one of the pumps or engines fail. Few details. *Flight*, February 16, 1939, page 172, 1 illus.

It Is Necessary to Measure the Atmospheric Pressure Outside of the Zone Disturbed by the Airplane, Otherwise Serious Errors of Altitude Can be Produced. M. Victor. The French "N.A.C.A." (G.R.A.), in collaboration with the French Institute of Fluid Mechanics, has developed and patented a new static-pressure "sounder," indications of which are always correct for the different flight conditions of the airplane. The sounder is in the form of a sphere pierced along a horizontal diameter with a venturi opening and is hollowed out inside into an annular chamber. Into this chamber open a tube taking the total pressure in the neck of the venturi, and a series of holes placed on the rear circle at 40° to the axis. Diameter of the sphere being 60 mm., the sounder can then be used at 10,000 meters altitude on an airplane attaining a speed of 700 km./hr. Long description abstracted from Technical Note No. 1 of the French N.A.C.A. *Les Ailes*, February 9, 1939, pages 7–8, 3 illus.

The New 30-Passenger Substratosphere Plane. Tell-Tale device on the Curtiss-Wright CW-20 transport checks for pilots the functioning of 47 details of operation, providing for taxiing, take-off, cruising, and landing, and further enables pilots to check on either of the two 1600-hp. Wright Cyclone engines. Photograph shows Tell-Tale panel on the instrument board and few details of the airplane are given. *U.S. Air Services*, March, 1939, page 21, 1 illus.

Nivar Remote Gauge. J. L. Hubert. Nivar fuel gauge described is said to permit the measurement of the quantity of fuel carried in a continuous and precise manner and operates on the Pascal principle, utilizing manometric tubes, simple and sure parts, without mechanical floats, and without electric transmissions, analogous to those which are used in the fixed installations. Arrangements are such that their indications are not altered by movements or inclinations of the installation. Gauge consists of indicating tube fixed on the instrument board, compensating system fixed on a mounting frame or on the reservoir itself, and connecting manifolds. Physical and mechanical conditions which the device must fulfill, and the design of the Nivar gauge for aircraft are described in detail. *L'Aéronautique*, January, 1939, pages 43–46, 4 illus., 3 equations.

Radio Tube for Altimeter Generates a 14-Cm. Wave. Practical radio tube generating an ultra-short wave 5½ in. long has been announced by W. C. Hahn and G. F. Metcalf of General Electric Company. Waves are short enough for the radio echo altimeter now under development to show pilots how high they are above the ground and to warn them of other planes nearby, and it can be directed like the beam of a searchlight. Few details. *Science News Letter*, February 25, 1939, page 124.

Ultra-Short Radio Waves Are Used to Reveal Hidden Objects. In the new method patented by C. W. Hansell, a device picks up the radiation either broadcast or reflected from the concealed object and constructs it into a visible picture on a surface covered with the chemical. In practice copper sulfate is coated on a screen and waves focused on it within a specially constructed evacuated glass tube. Action of short radio or infrared waves dehydrates the salt and turns it white. Principle may be of help in airplane navigation in the fog. Brief note. *Am. Meteorological Soc., Bul.*, November, 1938, page 412.

Electrical Equipment

High-Voltage A. C. for Aircraft. In the scheme being developed for aircraft by Rotax, Ltd., it is proposed to install duplicate gasoline-engine-driven alternator sets each giving 5 or 10 kw. at 110 volts, 400 or 800 cycles. Comparative weights for parts of a 2-kw. d.c. and a duplicate 10-kw. a.c. system are shown, giving a weight of 123 lb./kw. for the d.c. system and 34.4 lb./kw. for the a.c. system. Advantages of the a.c. self-contained power plant over a d.c. generator-cum-battery set in which the generator is driven by one of the main engines are described. It is predicted that 20-ton and even smaller aircraft will be fitted with a.c. systems. *Flight, Aircraft Engr. Sup.*, February 23, 1939, page 8.

New Eclipse Generators. Eclipse 30-volt engine-driven aircraft generators produce 1500 watts and are available for either 12- or 24-volt d.c. operation. Few details. *U.S. Air Services*, March, 1939, page 33, 1 illus.

Alternating Current for Aircraft. W. Esden. In the scheme now being developed by Rotax, Ltd., the proposal is to install duplicate gasoline-engine-driven alternator sets each to give 5 or 10 kw. at 110 volts and at 400 or 800 cycles. Comparative weights for a 2-kw. d.c. and a duplicate 10-kw. a.c. system are given. The author points out the advantages accruing from the use of an a.c. self-contained power plant over a d.c. generator-cum-battery set in which the generator is driven by one of the main motors. *Aeroplane*, February 1, 1939, page 137.

Fuel Tanks

Rubber-Impregnated Fabric Makes Vibration-Proof Tank. Mareng fuel cell is made of thin fabric impregnated with synthetic rubber, and not only eliminates the need of gas-tight metal fuel containers, but also offers vibration-proof characteristics far in excess of accepted tolerances. Description of new type fuel tank used in Glenn L. Martin landplanes and flying boats. *Aero Digest*, February, 1939, pages 78, 81, 2 illus.

Testing Apparatus

A High-Speed Mechanical Recorder. H. V. Neher. Mechanical recorder described has a resolving time of 0.8×10^3 sec. and will follow regularly spaced pulses at the rate of 1200 per sec. and should miss no more than 1 percent of pulses spaced random in time at an average counting rate of 10 per sec. Circuit is also described giving a pulse of short enough duration and at the same time of sufficient magnitude to satisfactorily operate the recorder. *Rev. Scientific Instruments*, January, 1939, pages 29–31, 3 illus.

A Portable Magnetic Crack Detector. New portable crack detector introduced by Metropolitan Vickers Electric Company is in the form of a thin hollow disk-shaped container filled with specially reduced iron dust carried in almost colloidal suspension in dry oil and with one or both sides transparent so that concentrations of iron dust can be seen. Short description. *Engineer*, February 24, 1939, page 258, 1 illus.

What Instruments Do for Industry. What instruments do for the ceramics, chemical, communications, food, forest products, iron and steel, machinery, nonferrous metallurgical, paper, petroleum, power, rubber, textile and transportation (aircraft, automotive and rail) industries is discussed by various authors. *Instruments*, Part I, January, 1939, pages 7–51, many illus.

1939 Instruments Index. Index to instruments and apparatus; directory; of laboratory supplies; directory of manufacturers and sole representatives; and instrument bookshelf. *Instruments*, Part II, January, 1939, pages 2–60.

Materials

Automotive Materials—New Developments. Asbestos-filled molding materials; hard carbide alloy for machining tough metals; G.E. improved magnet wire; prefinish treatment of zinc surfaces; rigid low-resistance lead anode for chromium plating; new Delco chemically processed fluid for hydraulic brakes; cleaner for removing stains from metals. Few details. *Automotive Industries*, February 18, 1939, pages 188–190, 1 illus.

Air Ministry Official Notices. Jointing materials (sheet) and jointing compounds approved by the British Air Ministry are listed. *Aircraft Engineering*, February, 1939, page 73.

Science and Industry. Metallurgical research on behavior of materials at high temperatures, forged magnesium alloys, cracking of boiler plates, and internal stress, as well as lubrication research on physical properties of surfaces, and a four-ball high-pressure lubricant testing apparatus are described. Research on buildings, roads and water pollution is also discussed. Excerpts from Report for Year 1937–38 of the British Department of Scientific and Industrial Research. *Engineer*, February 17, 1939, pages 208–210.

Metals

Heat Resisting Alloys for the Exhaust-Gas Turbine. F. Bollenrath, H. Cornelius, and W. Bungardt. Creep and heat-resisting properties of 24 German alloys were studied for their suitability as exhaust-gas-turbine materials. Results of the tests are described. Special attention was paid to ratio of creep strength to specific gravity, coefficients of thermal expansion, effects of repeated heating and cooling, and stability of the microstructure. Tests were also carried out to investigate the scaling resistance of selected alloys to an atmosphere produced by burning gasoline with or without additions of ethyl fluid. Long abstract from Luftfahrtforschung, September 10 and October 10, 1938. *Metal Treatment*, Winter 1938–39, pages 182–187, 2 illus., 7 tables.

Recent Developments in Powder Metallurgy. W. D. Jones. Principles on which sintering and fritting of metal powders depend, a number of recent applications of the technique of powder metallurgy, and directions in which future progress is probable. Manufacture and characteristics of compacts made from cast-iron powder, and of porous magnesium flares, porous bronze and other bearings, and porous precious metal products are described. Alloys made by the powder method for use in electrical contacts, possibilities of light alloys made from powders, and preparation of alloys in powder form for subsequent sintering into compacts are considered. *Metal Treatment* Winter 1938–39, pages 145–149, 152, 1 illus.

150th A.I.M.E. Assembly Attracts 2500. "Some Things We Don't Know About the Creep of Metals," H. W. Gillett. "Corrosion Characteristics of Stainless Steel," H. A. Smith and S. P. Odar. "The Nature of Passivity in Stainless Steels and Other Alloys," H. H. Uhlig and J. Wulff. Long abstracts of these papers and short abstracts on papers dealing with high-purity metals (zinc, tin, lead, nickel, platinum, and silicon). *Iron Age*, February 23, 1939, pages 38–45.

Applications of Supersonic Waves. Applications of supersonic waves to improve metallic constructional materials and to the testing of materials. Mechanical, thermal, vibrational, chemical and electrochemical effects of supersonic waves are discussed. Experimental results showing effect on grain refining action takes place and that distribution of one metal on another can be altered. Photomicrographs show melts of antimony, duralumin and silumin solidified under action of sound waves and identically similar metals not subjected to sound waves. *Metallurgist Sup., Engineer*, December 30, 1938, pages 177–179, 3 illus.

Corrosion and Protective Coatings

Some Corrosion Problems Relating to Modern Aircraft. A. J. Sidery and J. W. W. Willstop. Features connected with the study of corrosion as applied to present-day aircraft. Effect of heat treatment on corrosion-resistance of aluminum alloys; effect of reheating on corrosion properties of duralumin; behavior of aluminum alloys under stress/corrosion conditions; influence of fuels on metals and alloys; organic protectives; precautions regarding joints and jointing materials; reduction of corrosion in riveted joints; radiator corrosion problems; alternatives to zinc chloride fluxes; corrosion in glycol-filled radiators; strength tests of solders; and reduction of glycol corrosion by inhibitors. Data are given on the corrosion of solders and of various metals by untreated and treated glycol after 120 hours at 130°C., and on the metallic impurities in glycol after flight tests. *Royal Aeronautical Soc., Preprint for Meeting*, January 19, 1939, 12 pages, 5 tables. *Metal Industry*, February 10 and 17, 1939, pages 179–181 and 208–212, 5 tables.

Alkaline Plating Solutions. A. K. Graham. Examination of anodic behavior. Permissible anode current density; anodic reactions; excessive polarization in alkaline solutions; anode-current density; and effects of temperature, solvent chemical, pH, impurities, carbonate insoluble anodes and agitation. American Electroplaters' Society paper. *Metal Industry*, February 24, 1939, pages 251–252.

Electrolytic Polishing of Metals. P. Jacquet. Methods and mechanism of electrolytic polishing and properties of the surfaces thus obtained are described. Attention is given to the electrolytes and current densities used and to the reflecting power of electrolytically, as compared with mechanically, polished surfaces. Influence of surface character of cathodes on the structure of electrodeposits is considered. Abstract from *Revue de Metallurgie*, February, March and April, 1938. *Metal Treatment*, Winter 1938–39, pages 153–155, 157, 1 illus., 1 table.

Phosphate Pre-Treatment in Finishing Sheet Steel Work. E. E. Halls. Phosphatizing is superior to other methods of ensuring adhesion, provides inhibitive properties, and enables ordinary grades of finishing material to be satisfactorily employed. It eliminates the need for a primer and simplifies the finishing process. Experiments described show that, when phosphatizing cannot be employed, effective alternatives are provided by red oxide or zinc chromate primings of selected quality. Table gives extent to which phosphatizing contributes to durability of enamel finishes on sheet steel work shown by salt spray test results on spot welded cabinets. *Metal Treatment*, Winter 1938–39, pages 170–174, 3 tables.

Iron and Steel

Alloy Steels in 1938. W. J. Priestley. Improvements due to zirconium-silicon and calcium alloys in steel making; silicon-aluminum-vanadium-zirconium for refining grain; vanadium for improving chromium steels; wider uses for complex chromium alloys; corrosion-resistant steels for spe-

cific purposes; more easy fabrication of stainless steels; special compositions for solving corrosion problems; stainless steels used in new forms; improved straight chromium steels; and columbium to improve impact strength and toughness. *Heat Treating and Forging*, January, 1939, pages 16–18, 23.

Temper Hardening of Steel and a Theory of Tempering. S. A. Main. Theory of precipitation hardening is discussed insofar as it has been used as an explanation of hardening experienced during tempering of some quench-hardened steels, including nickel-chromium, nickel-chromium-molybdenum, nickel-chromium-molybdenum-vanadium, molybdenum-vanadium, and other steels.

Explanation is based on a particular view about the constitution of quenched steels and their behavior when heated. Phenomena associated with tempering are attributed to the relations between austenite and martensite. Latter constituent is supposed to contain carbon as minute particles which combine with iron during tempering to form carbide. *Metal Treatment*, Winter 1938–39, pages 158–164, 11 illus.

Effect of Titanium and Vanadium on Forged Pearlitic Manganese Steels. G. F. Comstock. Vanadium is shown to be an alloying element which has a hardening effect on this type of steel, usually increasing strength and sometimes reducing ductility and impact resistance. Titanium has a softening effect, generally decreasing strength but giving decidedly higher ductility and impact resistance. Both show a tendency to reduce grain size. Results of tests. *Iron Age*, February 16, 1939, pages 27–32, 8 illus., 1 table.

NONFERROUS ALLOYS

Defects in Non-Ferrous Ingots. G. L. Bailey. Causes and elimination of defects in the ingot which persist throughout the rolling process. Discussion covers surface defects such as oxide patches, defects eliminated in pouring in a reducing atmosphere, defects in the Durville process, laps and splashes, blowing and mold defects, and inverse segregation, and such internal defects as evolved gases, entrapped gases, defects from position of the mold, and shrinkage. To be continued. Midland Metallurgical Societies paper. *Metal Industry*, February 24, 1939, pages 239–242, 4 illus.

Plating of Magnesium Alloys. New process developed by F. C. Katon and H. Webb enables magnesium alloys to be plated by any of the normal plating processes. Part to be treated is immersed in an aqueous bath for a couple of minutes, then swilled in cold water, and then placed in a special zinc bath where it remains for 10 to 15 minutes. After removal, part is again swilled and is ready for plating by any kind of a process. Microscopic examination has shown complete regularity and cohesion of zinc to magnesium indicating that the "keying" has been absorbed into the zinc coating and forms a perfect bond. No traces of galvanic action between magnesium and deposits have been found. Application to rubber is also referred to. *Flight*, February 16, 1939, pages 172–173.

Magnesium as an Engineering Material. Compositions of cast and wrought magnesium alloys used in Germany; effect of temperature on properties of magnesium alloys as shown by the D.V.L. research; great influence of form of section tested on fatigue strength of magnesium alloys; and precautions in drop forging, extrusion, and machining. From *Maschinenbau/der Betrieb*, Nos. 11–12, 1938. *Metal Treatment*, Winter 1938–39, pages 175–176, 181, 2 tables.

Ageing. Marie L. V. Gayler. Factors affecting age hardening of aluminum alloys, including quenching temperature, temperature of heat treatment, chemical composition, grain size, cold work including lattice distortion, and quenching stresses are discussed. The original duralumin theory is explained and later results altering the theory are reviewed. Great importance of the phenomenon of aging to industry, especially corrosion resistance of alloys, is taken up and further investigations on the effects of grain boundaries, diffusion, and cold work are recommended. *Metallurgist Sup., Engineer*, December 30, 1938, pages 181–185.

Beryllium Alloys in Automotive Production. H. W. Perry. Properties of beryllium-copper, beryllium-nickel and beryllium-nickel-chromium-iron alloys, heat treatment, removal of scale formed by forging, annealing or heat treating, soldering and electric welding are discussed. Reference is made to results obtained at Wright Field with beryllium-aluminum alloys. *Automotive Industries*, February 18, 1939, pages 184–189, 11 illus.

Some Aspects of the Mechanical Properties, Uses and Manipulation of Aluminum Alloys. F. R. C. Smith. Problems and enquiries encountered during several years contact with the aircraft industry. Mechanical properties of aluminum alloys used in aircraft structures and effect of methods of fabrication and service conditions on these properties; uses of aluminum-alloy sheet, extrusions, castings, and forgings; methods of manipulation including heat treatment, forming, machining, spot welding, and gas welding. *Jour. Royal Aeronautical Soc.*, January, 1939, pages 1–18, 14 illus., 1 table.

TESTING OF METALS

Magnaflux Indications Interpreted. B. Clements. Three types of equipment and applications are listed and various types of imperfections indicated by these devices are described, including heat-treating cracks, laps, bursts, inclusions, grinding, machining tears, and fatigue cracks found on parts in service. *S.A.E. Jour. (Trans.)*, February, 1939, pages 68–71, 11 illus.

Magnaflux—What Does It Show? J. B. Johnson. Magnaflux testing as an important adjunct in connection with inspection of aircraft parts fabricated from magnetic materials. Several types of defects indicated by magnaflux are described which have been found in routine inspection and examination of a large number of parts in service in engines, airplanes and accessories operated by the U.S. Army Air Corps. *S.A.E. Jour. (Trans.)*, February, 1939, pages 59–67, 13 illus.

Measurement of the Thickness of Metal Plates from One Side. A. G. Warren. Method is particularly applied to determination of extent of corrosion, and is a conductivity method not depending upon any previous knowledge of specific conductivity of the material. Conductivity is automatically eliminated during computation and essential relationships used are purely geometrical and do not depend upon physical properties of the material. *Instn. Electrical Engrs., Jour.*, January, 1939, pages 91–95, 8 illus., table, many equations.

Testing Metals for Wear by Friction Discs. Wear tests described were performed on the Skoda-Sawin testing machine, working tool of which is a smooth rotating disk of hard metal 30 mm. in diameter and 2.5 mm. in width, which under a constant load grinds an impression in a fixed test piece. Precision of work done by disk and maintenance of its grinding ability was checked by repeated testings on Johansen, Zeiss and other gauges. Greatest hardness did not always correspond to greatest resistance to abrasion by the Widia disk. *Engineer*, February 10, 1939, pages 184–185, 10 illus.

The Bragg Admiralty Laboratory Inspection Department, Sheffield. Description of building, of the metallographic spectrographic sections of the nonferrous metal laboratory, and of various heat-treatment operations. *Engineering*, February 17, 1939, pages 199–200, 4 illus.

Relation between Mechanical Properties and Service Results. L. W. Schuster. First issue—Izod test, and failures in service. Second issue—Examples of types of failure of welded parts; corrosion fatigue failures; torsional vibration failures and longitudinal and transverse tests; and failure from induced brittleness. Continued. British Institute of Metals paper. *Heat Treating and Forging*, January and February, 1939, pages 28–31 and 68–71, 22 illus., 2 tables.

Radiographic Stress Measurements Going Beyond the Yield Point of Tensile Bars of Unalloyed Steel. F. Bollenrath, V. Hauk, and E. Osswald. For an explanation of the decrease in stress on bending bars in the cross-sectional part stressed beyond the yield point, the elongation was measured radiographically and mechanically on tension bars with square cross-section as a function of load up to a total elongation of 11 percent. With exceeding of the yield point, the development of an unequal stress distribution over the cross-section and consequent internal stresses were observed. The compressive internal stresses extend over approximately one-half of the cross-section. D.V.L. report. *V.D.I.*, February 4, 1939, pages 129–132, 7 illus., 1 table.

Calculation of Errors Resulting from Auxiliary Stresses in Photoelasticity. A.Kuske. In a previous publication it was demonstrated how practical unstressed models can be made of phenol resin for photoelasticity purposes, but this is not always possible. Where production models are to be used the auxiliary stresses can be determined and considered in the evaluation. Methods are described. Superposing two-dimensional stress conditions, superposing double refraction on model bodies, errors as a result of auxiliary stresses, and marginal effect are considered. *V.D.I.*, December 17, 1938, pages 1455–1458, 9 illus., 1 table, 8 equations.

WELDING

Notes on Welding Practice. J. G. Waterworth and A. R. Mowbray. Recommendations for the gas welding of medium-carbon, manganese and chromemolybdenum steels, stainless steels, and aluminum alloys of sheet and tube for aircraft structures. *Aircraft Engineering*, January, 1939, page 27, 4 illus.

Welding Coated Steel—Review of Literature to July 1, 1937. W. Spraragen and G. E. Claussen. Welding galvanized iron (spot, fusion and bronze welding); welding nickel-clad steel (fusion and spot welding, iron pickup, mechanical properties and flame cutting); welding monel-clad steel and Iconel-clad steel; welding stainless clad steel (fusion and resistance welding and flame cutting); welding of tin-plate, terne plate, chromium-plated steel, cadmium-plated steel, aluminum-clad steel, copper-clad steel, and oxide-coated steel; and suggested research problems. Correlated abstract. *Welding Jour., Welding Res. Sup.*, February, 1939, pages 33–43, 3 illus., 6 tables.

Plastics

Properties of Hot Pressed Synthetic Resins According to DIN 7701. R. Nitsche. Property values of hot-pressed synthetic resins are discussed in regard to revision of the German DIN 7701 standards. Materials include phenol resin with inorganic filler, with sawdust filler, with textile-fiber filler and with cellulose filler, as well as urea formaldehyde resin with organic filler. *V.D.I.*, February 11, 1939, pages 161–164, 11 illus., 2 tables.

The Swelling of Wood. N. A. De Bruyne. Possibility of preventing the swelling of wood by use of synthetic resins is discussed, and it is concluded that complete immunity from swelling could only be attained at the expense of the strength of the wood. An original analysis is given which enables the magnitude of swelling to be predicted, and the expression derived is shown to be in agreement with experiment. *Aircraft Engineering*, February, 1939, pages 44–46, 3 illus., 2 tables, 7 equations.

Rhodoid. Rhodoid transparent acetate sheets have been approved by the British Air Ministry for use on all aircraft contracts. Physical and mechanical properties are described. *Aeroplane*, February 1, 1939, page 148.

Towards an Ideal. Col. V. Clark's rapid and cheap method of production of fuselages and wings is referred to with comments on what is being done on plastics in England. Rotor blades made of impregnated and compressed wood have been flying for some months in England and have given complete satisfaction. Hollow compressed and impregnated propeller blade seems to have the qualities of weathering and grading in density which are required for operation with engines of 2000 hp. or more and manufacture is not a very difficult matter. Brief editorial. *Flight*, February 16, 1939, page 150.

Rubber

How Wilkinson Linatex Helps. Drawing shows how Linatex is used to seal Perspex windows of the Empire flying boat. Windows can be pushed out to provide an exit in an emergency. Linatex is a special form of rubber manufactured in sheets in British Malaya, the process of manufacture preserving the amorphous structure of the rubber. Linatex can be cold-cemented together and can be bonded to metals, wood or fabric. *Aeroplane*, February 1, 1939, page 149, 1 illus.

A Synthetic Rubber. Hibudine, developed by Paul Quinn, Ltd., can be produced either in liquid form, for application to sheets or castings in steel, aluminum, duralumin, magnesium, and other metals, or molded to any form. It is specially compounded to resist abrasion from flying particles as against direct contact friction. It is also used as a bonding medium between friction linings and opposed surfaces of clutch plates and brake diaphragms where it takes the place of rivets. Oil cooler in which tubes are bonded together with Hibudine synthetic rubber compound is illustrated. Few details. *Aircraft Engineering*, January, 1939, page 31, 1 illus.

Meteorology

A Study of Aircraft Icing. N. L. Hallanger. Important factors in the formation of ice on aircraft are said to be potentially unstable air and the lifting by fronts and orographical slopes along with wind velocity, all contributing to the production of vertical currents. Velocity of vertical currents in turn controls the size of the drops of water, rate of condensation and amount of water that can be held in suspension.

In order that icing may be forecast reasonably well, all of the factors that might influence these vertical velocities must be taken into account. To be practical this must be done quickly, a requirement for which experience in analyzing the effect of each factor is a valuable asset. Analysis of information obtained by United Air Lines' pilots flying in and out of Oakland, California, on regular schedules. *Am. Meteorological Soc., Bul.*, November, 1938, pages 377–381, 1 table.

The Meteorological Problem of the North Atlantic. F. Entwistle. Meteorological considerations in the selection of one of the three alternative routes across the North Atlantic; meteorological organization for transat-

lantic flights; application of meteorological information supplied prior to a transatlantic flight; choice of altitude for flying; upper wind observation; the necessity for upper-air research; and the French Carimare "stationary" ship for meteorological observations of the Atlantic. Long discussion of paper included. *Jour. Royal Aeronautical Soc.*, February, 1939, pages 69–104, 13 illus., 6 tables.

The Triple Point of Water and the Icing of Airplanes. D. Arenberg. Water can exist at the triple point only as a carefully controlled laboratory experiment. Maintenance of triple point during icing, even if possible for solutions, would require highly uniform conditions of salinity and particle size as well as temperature and pressure within a large cloud stratum. *Am. Meteorological Soc., Bul.*, November, 1938, pages 383–384.

Valley Fog Caused Largely by Decrease of Pressure. W. P. Briggs and P. E. Church. It is strongly recommended that whenever air temperature and dew point are approaching each other and their difference is less than 3°F. that the air temperature and wet-bulb temperature be reported in either quarters or tenths of a degree. Probably many of the "surprise" local fogs that an aviator observes in valleys in mountainous areas may be due primarily to cooling of trapped nearly saturated air by decrease of pressure.

To determine whether air mass was the same at all four stations in the west (Chehalis, Castle Rock, Tacoma and Washington) before and during the fog, equivalent-potential temperatures were calculated, which showed that Seattle and Tacoma had different air from the fogged stations. Analysis made by the authors, one of whom is a pilot on United Air Lines. *Am. Meteorological Soc., Bul.*, December, 1938, pages 430–433, 1 table.

Effects of Tropospheric Conditions on Radio Transmission in China. E. Gherzi. When transmitting and receiving stations were under one and the same type of air mass, signal at all seasons at the same hours was quite strong and steady, but as soon as the Irkutsk station was, for example under an extratropical cyclonic warm front while Shanghai was under an anticyclone, strength of signal greatly dropped and fading was noticeable. *Am. Meteorological Soc., Bul.*, December, 1938, pages 402–404.

Some Comments on Father Gherzi's "Constitution of Typhoons." C. E. Deppermann. Criticisms of the article and its lack of adequate data. Excerpts from "Typhoons Originating in the China Sea" by C. E. Deppermann are given at the end of the article. *Am. Meteorological Soc., Bul.*, November, 1938, pages 369–377, 2 illus., 1 table.

The Soviet Polar Enterprise, Some Preliminary Results. R. N. R. Brown. Currents and winds of the Arctic are discussed. Conception of the Arctic as a region of continuous high pressure must be modified since cyclones penetrate to the region of the North Pole and bring relatively warm weather. New magnetic observations will be a great help to future aviators, both in placing and removing floating parties of observers. Aerial transport between Europe and the far East will also be facilitated. Short abstract from *Nature*, March 12, 1938. *Am. Meteorological Soc., Bul.*, November, 1938, page 411.

The Thermal Structure up to 20 Kilometers over Franz Joseph Land. Mean temperature-height curves for each month are illustrated, and essential facts about types and frequencies of the lapse rates are given in tables. Data are taken from "Vertical Temperature Gradients above Franz Joseph Land," by I. G. Guterman in Meteorologia I Hydrologia, 1938 (Russian). *Am. Meteorological Soc., Bul.*, December, 1938, pages 433–434, 1 illus., 11 tables.

Fuels and Lubricants

Effect of Pressure on Lubricating Greases. B. B. Farrington and R. L. Humphreys. Empirical equation has been found which, except for a short initial period, represents the amount of oil pressed from a grease in a given time by the Herschel grease press. Ultimate oil loss for various pressures has been calculated by means of an oil-loss equation for a number of greases. Viscosity of the petroleum oil contained in a grease has been shown to effect materially the initial oil-loss rate without changing the ultimate oil loss for greases of the same consistency. *Industrial and Engineering Chemistry, Ind. Ed.*, February, 1939, pages 230–235, 8 illus., 7 tables.

Straightrun Gasoline Made for Aviation Purposes. L. J. Coulthurst. "It has been estimated that 90 percent of the U.S. Army Air Corps aircraft fuel consumption for 1938 will be of the 100-octane grade, and there is no doubt that commercial planes will be using 100-octane motor gasoline exclusively in the very near future."

Preparation of 100-octane aviation gasoline by blending 50 percent of 70- to 76-octane straightrun gasoline with 40 percent of commercial isooctane, 10 percent of isopentane, and a maximum of 3 cu.cm. of tetraethyl lead per gallon is mentioned and a process is described which is used by one of the major refining companies for debutanizing and rerunning a considerable variety of stocks to produce 70–76 octane straightrun gasoline. *Oil & Gas Jour.*, March 9, 1939, pages 46, 48, 2 illus., 1 table.

Aircraft Engine Lubrication. E. L. Bass and C. H. Barton. *S.A.E. Jour. (Trans.)*, January, 1939, pages 8–14, 4 illus., 2 tables.

Bearings

Comparative Tests of Metals and Synthetic Resin Molded Bearings. R. Strohauer. White-metal, bronze, zinc, aluminum, magnesium, Buna, Mipolam and reinforced molded synthetic-resin bearing materials were investigated in the bearing testing machine, developed for this purpose. Various quantities of lubricating oil were used in the tests and materials were subjected to the most varied conditions of loading, bearing temperature, and friction moment.

On this machine oil temperature is controllable. Temperature measurements are made by means of two thermo-elements in the highest stressed parts of the bearing below the running surface and recorded by means of multithermographs. R.p.ms. up to 5000 are possible, which, for 40-mm. journal diameter, is a sliding speed of 10 meters/sec. At a bearing range of 20 mm. corresponding to an $l/d = 0.5$, surface pressures up to 500 kg./cm.^{2} can be applied.

In the test report, distribution of temperatures in the bearing and their behavior as a function of load and time is treated extensively. The molded synthetic-resin materials under pressure lubrication, after carefully tested operation, were found to be equal to the metal bearing with reference to sliding properties. Their properties in emergency operation may be regarded as splendid. Extracts from investigation directed by A. Thum of State Materials Testing Institute, as well as discussion by E. Heidebroek, H. Ernst, K. H. Bussmann and E. Amedick. *V.D.I.*, December 17, 1938, pages 1441–1449, 13 illus.

Engine Design and Research

Auxiliary Connecting Rods. H. Wiegand. Strength of aircraft-engine components. Distribution of stresses in a connecting rod is illustrated and discussed in detail. In a new design material was removed from the recess which was formerly circular or parabolic, and at the juncture of head and shank, and was added to the boss. Question of material is taken up and examples of defective material are given to illustrate how, with incorrect production of material and subsequent treatment, the slightest negligence in machining can have very serious consequences. Translated from Luftwissen, August, 1938. *Automobile Engineer*, January, 1939, pages 3–5, 12 illus.

Motor Car Interference. F. R. Strafford. Methods employed in suppressing radiation from ignition systems of automobile engines, from the point of view of reception, particularly television reception, external to the vehicle. Tests of suppressors fitted between distributor and plugs are described. *Wireless World*, February 9, 1939, pages 130–132, 2 illus.

Observations on the Compression Ratio. H. J. Venediger. Investigation of theoretical engine operation methods and the ideal thermal efficiency thereby attainable from the viewpoint of compression and expansion ratios shows that efficiency loss is considerable as the result of reduced expansion. Compression ratio is not a constant number with reference to volumetric ratio, but is variable and dependent on operating conditions of the engine. This explains the behavior of engines under various operating conditions and should be observed in detonation investigations.

The term "effective compression ratio" is introduced. This is always smaller in the case of four-cycle engines without supercharging than the volumetric ratio of conventional conception. In case of two-cycle engines effective compression ratio at full load is about 7.5 percent greater than the volumetric ratio when length of outlet opening is not subtracted. In the other case it is about 12 percent less. Latter method is the only correct method of calculation. Compression ratio today is a construction quantity of the second order. Importance lies altogether in its relation to detonation. Long discussion. *A.T.Z.*, January 25, 1939, pages 27–37, 24 illus., 5 tables, 20 equations.

Progress in Mechanical Vibration Research. H. G. Kuessner. Papers presented at the symposium on vibration held by the V.D.I. October, 1938, are reviewed, including the following subjects: vibration measuring technique; mechanical induced vibration on machines and vehicles; vibrations induced by flow over machines and vehicles; ground vibration; and gyro oscillations. Among the papers of interest are: "Vibration in Helical Valve Springs," A. Hussmann. "Vibration Problems in Elastic Suspension of Aircraft Engines," J. Meyer. "Flow-Induced Resonance Vibrations," F. Michel. "Information on Wing Flutter on Airplanes," H. Voight. "Application of Vibration Calculations to the Field of Gyro Theory," M. Schuler. "Vibrations of the Gyroscope Elastically Coupled with the Mass," K. Magnus. "Application of the Complex Method of Calculation in the Theory of Gyroscopes," L. Stellmacher. *V.D.I.*, February 11, 1939, pages 149–155.

Sleeve-Valve Development. A. H. R. Fedden. In regard to direct fuel injection it is considered that control of turbulence might be the most important factor in future development. Experience with small high-speed Diesels has shown that direct injection of small quantities of fuel presents no insuperable difficulty. It should be possible to inject the fuel-air mixture very accurately over a wide range of operating conditions and to use fuels of low volatility. Most of the promising geometric forms could be accommodated to the existing type of sleeve drive and engine will undoubtedly make its appearance in multibank radial and H form.

Development of the Bristol sleeve-valve engine is traced and comparative data are given for single-cylinder units of the Perseus and Mercury types of engines, and Aquila and poppet-valve cylinders are also compared. Results of recent test to discover the limit of output of the sleeve-valve unit are given. Very long abstract of Royal Aeronautical Society paper with discussion by D. R. Pye and others. *Flight*, February 16, 1939, pages 160d–160h, 161, 19 illus., 2 tables. *Aeroplane*, February 15, 1939, pages 207–213, 17 illus., 1 table.

Status of Knowledge of Mixture Formation in Otto and Diesel Engines. K. Zinner. Mixture formation in Otto-cycle and Diesel engines is discussed and, for the latter, injection regularity, volumetric distribution and vaporization, and influence of air movement on the mixture formation, are considered in detail. *V.D.I.*, February 11, 1939, pages 141–147, 17 illus.

Cooling Deflector Design. J. Engel. Fundamental factors in the design of aircraft-engine cooling deflectors including: close fitting and location of deflectors as dependent on gill opening and size and spacing of fin; materials for deflectors; mounting supports and brackets; mounting methods; and cooling the accessory compartment. Certain parts of deflectors cast or formed directly on the head and designed so that deflector metal will assist in heat transfer are suggested. *Western Flying*, October, 1938, pages 22–23, 1 illus.

Cylinder-Bore Wear. A. Taub. Conditions required to offset bore wear are discussed, including: thermostatically-controlled cooling for water; crankcase ventilation to eliminate effects of blowby in the sump; adequate oil supply to cylinder bores; complete control of lubricant at the piston rings; control of gas blowby at the rings; leanest possible mixture ratio; close attention to type of fuel to ensure it is properly vaporized; uniform metal temperatures; spark advance mechanism free from timing errors; and oil film. Long discussion. Institution Mechanical Engineers paper. *Engineering*, February 10, 1939, pages 169–171, 7 illus.

Recent Developments in Piston-Ring Materials. B. A. Yates. Composition, structure and surface finish which should go into the modern piston ring. Causes of piston-ring wear are analyzed and classified as abrasion, corrosion and erosion. Various types of metallic and non-metallic coating materials employed to reduce scuffing or scoring are considered. Test results discussed indicate that superficial coatings reduce piston-ring wear from scuffing and erosion and that a very thin coating of tin is more effective. *S.A.E. Jour. (Trans.)*, February, 1939, pages 49–58, 19 illus., 3 tables.

Engine and Fuel Testing

Detonating Value or Detonating Limiting Values of Engines and Fuels. H. H. Berg. Evaluation of fuels for motor vehicles so far has been by means of the detonating value determined with the help of the engine, that is octane number. For obtaining better possibilities of comparison with other fuels, the evaluation of detonating limit values, or detonating limit curves, especially as a function of excess air number, is of advantage. Properties or detonating behavior of vehicle engines likewise cannot be characterized by a single value. Instead they can only be comprehended by similar limiting values. Close relations between fuel, operating requirements, and engine design require extensive observation of the various influences. Detonating limit value of fuel on the basis of recent discoveries in the field of fuel production can be arbitrarily changed. Furthermore, by construction measures, especially the use of sodium-filled exhaust-valve seats, even on small engines, the detonating limit values can be increased, thus enabling greater requirements for fuel and engine. *A.T.Z.*, January 25, 1939, pages 41–43, 1 illus., 1 table.

A Double Measuring Stand for Aircooled Aircraft Engines with Alternating Current Arrangement. K. Madsen. Alternating-current asynchronous machines as braking means for full-sized engine test stands with sliding resistance control require a special arrangement of the brake setup. For the production of special cooling effects, such as occur in the case of dive flights and climb, the constant control of the airspeed in the jet between 500 and 150 km./hr. is required. For radial engines, in the case of the best possible cowling of aircraft engines, pressures up to 1200 mm. of water in the pressure chamber were produced by means of high-pressure centrifugal blowers with adjustable alternating-current drive. Description of electrical equipment and illustration of a.-c. brake position on the streamlined concrete foundation of which 1800 to 2800 b.hp. is developed at 1050 to 1750 r.p.m. *E.T.Z.*, February 2, 1939, pages 121–125, 6 illus.

A New Apparatus for Measuring Blowby. New apparatus developed at the D.V.L. for measuring rate of blowby into engine crankcases makes use of the pressure difference on opposite sides of an orifice plate inserted into the breather of the crankcase. Pressure difference is measured by means of an apparatus converting pressure variations into electrical impulses. Measurement of pressure difference on opposite sides of the orifice plate is effected by means of a pressure gauge of the inclined-tube type arranged in helix form and filled with mercury. Description of apparatus is given in this abstract from *A.T.Z.* December 10, 1938. *Automotive Industries*, March 4, 1939, pages 318–319, 2 illus.

Noise Detection. Methods of tracing sounds in engines and other mechanisms are discussed and a portable phonometer used by a leading maker of Diesels is described. Device consists of microphone, amplifier, sound filter and indicating instruments and is used principally for measuring noise produced by fans, blowers, engines, and suction and exhaust piping. Sound filter can be cutout of circuit and an oscillograph inserted instead of the indicating instrument. *Automobile Engineer*, January, 1939, page 12.

What Happens in the Cylinders? R. Rabion. Maximeter described was developed by Retel and Tchang-Te-Lou, to measure maximum pressures in the engine cylinders. Device consists of a membrane, one face of which is submitted to the pressure of a neutral gas holding it in electrical contact. When pressure in the cylinder is higher than that of the neutral gas, the membrane is raised and contact broken, provoking in a secondary circuit an extra current sufficient for lighting a neon indicating tube.

In measuring the maximum point of the pressure attained in each cylinder for each explosion, this equipment has shown that variations of power up to 50 percent occur between different elements of the same engine. If one wishes to obtain a maximum power and minimum fuel consumption, it is then indispensable that these pressures should be equalized. *Les Ailes*, January 19, 1939, page 7, 5 illus.

Making the Temperature Fields Visible by Means of Coats of Paint Influenced by Temperature. F. Penzig. Point measurements to determine the temperature distribution on the surface of a body take time and, in addition, in arrangements of temperature measuring apparatus on the test body it is possible that measured values are distorted as a result of heat transfer or change of flow conditions of the cooling air. This can be prevented by coating the test body with paint, the colors of which so change with temperature that the temperature values can be concluded from them. It is of special advantage when the colors remain after cooling so that subsequently temperature distribution can be determined for machine parts not visible in the test.

Investigation of aircooled engine cylinders, and the temperature distribution measurements on pistons and other engine parts, vehicle parts, and heating apparatus are discussed and demonstrated in colored photographs. *V.D.I.*, January 21, 1939, pages 69–74, 20 illus.

Notes on Aero Engine Research. P. H. Rayner. Various types of electronic engine indicators are described including the electromagnetic indicator with moving coil or with moving diaphragm, and the resistance, capacitance, piezo-electric, high-frequency (condenser, inductance, magneto striction, and inverse-Wiedemann), and photoelectric indicators. Amplifier and time-sweep units, cathode-ray oscillograph engine indicator for examining engine detonation, fuel-air ratio indicators, and tests of exhaust-turbine-driven superchargers are discussed. *Jour. Royal Aeronautical Soc.*, January, 1939, pages 19–32, 16 illus.

The Piezo-Electric Indicator. Zeiss Ikon engine indicator has a standard pressure element containing within a housing about the size of a spark plug, a sleeve within which is a pile of nine piezo-electric quartz plates. Bottom of the sleeve is closed with an elastic membrane which maintains the quartz pile in an accurately predetermined state of compression. At lower end of the threaded portion a sealing membrane prevents the combustion from penetrating into the quartz chamber. Behind the sealing membrane is a mushroom-shaped pressure transmission piston supporting the membrane over its whole surface.

Sealing membrane is given only a very slight permanent tension and is almost inelastic so that it is incapable of transmitting disturbing forces to the quartz pile. It also has a negligible temperature coefficient. For supercharged aircraft engines watercooled elements can be employed. Long description of device which, in addition to recording pressure-time diagrams, can also be used for observing or photographing pressure-volume or pressure-crank-phase diagrams. *Engineer*, February 3, 1939, pages 152–153, 7 illus.

Temperature-Sensitive Colors. F. Penzig. "Thermocolor" paints developed by I.G. Farbenindustrie A.-G. and used to indicate engine temperatures in tests, change their colors at definite temperatures. It is claimed that the colors are fast and do not change on cooling and that there are clear color differences, the changeover from one color to another being quite sharp. "Thermocolor" consists of metallic salts which at definite temperatures give off water, carbon dioxide, or ammonia and at the same time change their color. Most practical paints and their color change and temperature are listed. Binder is a synthetic resin and coating is not attacked by either oil or gasoline and adheres firmly at high temperatures which destroy the synthetic binder. Abstract from *A.T.Z.*, January 25. *Automotive Industries*, February 18, 1939, page 190. Original article with table of paints and temperatures, and colored plate showing temperature distribution on an aircooled aircraft-engine cylinder. *A.T.Z.*, January 25, 1939, pages 38–41, 8 illus., 1 table, 2 illus. on suppl. plate.

Engine Manufacture

DeHavilland Gipsy Twelve Production. Employment of magnesium; methods of making the top cover, supercharger casing, impeller, cylinder, cylinder head, connecting rods, piston, and bolts; subassembly of cylinder-head, crankshaft, and top cover; and assembly of the engine. *Aircraft Engineering*, February, 1939, pages 57–60, 8 illus.

Engines

The Alvis Leonides in the Air. "Preliminary reports of the flying trials of the new Alvis nine-cylinder aircooled radial which develops 450 hp. for take-off are definitely good." Few details of the engine and description of a test flight in a two-seater version of the Bristol Bulldog fighter. One feature of the engine is the provision for driving alternative assemblies of accessories on the back cover. This has been done by designing a range of back covers with various arrangements of drives. *Aeroplane*, February 22, 1939, pages 240–241, 4 illus.

American Aircraft Engines. Two-page table of characteristics and performances for 91 American aircraft engines. *Automotive Industries*, February 25, 1939, pages 244–245, 1 table.

Engines for 1939. Table giving specifications for 69 American aircraft engines, and photographs. *Aviation*, February, 1939, pages 54–57, 21 illus., 1 table.

French Engines at the 16th Paris Aero Show. P. Leglise. The following French engines are described, some in great detail with many drawings of parts as indicated by an asterisk:

Nationalized industry—Clerget *14-F 14-cylinder twin-row 600-hp. radial air cooled and *16H 16-cylinder 1600-hp. liquid cooled vee heavy-oil engines, latter having a turbo supercharger for each set of four cylinders (pumps, injectors, and turbo supercharger described); Lorraine *Sterna 120 900-hp. 12-cylinder vee with long shaft driving two propellers and developed for the Koolhoven F.K.55, *Algol 120 500-hp. 9-cylinder radial, and Sirius 112 18-cylinder 1000-hp. radial; Farman N.C.C.1 centrifugal supercharger having three stages, two of which are disengagable.

Private industry—Bristol engines to be built in France by Als-Thom; Bloch 4A1 95-hp. and 6Bl 180-hp. inverted inline; Coatalen 12 Vrs 550-hp. 12-cylinder vee heavy-oil engine having improvements lowering fuel consumption to 151 gr./hp.hr.; Gnôme Rhône 14-cylinder two-row radials, the *14-M 660-hp., 14N.21 1030-hp., 14N.50 1200-hp., 14N.O, 14N.1, 14N.2, 14N.3, 14N.4, 14N.5, 14N.20, 14M.6, 14M.7, 14M.8, and 14M.9; Hispano-Suiza *90 2000-hp., three versions of the *12Y liquid-cooled and *14-AA and *14-AB aircooled radials, 12-X, 14-Ha and 14-Hb and 9V, and the Hispano-Suiza wind tunnel; *Jalbert Loire 4-cylinder 130-hp. inverted inline and 16-cylinder 500-hp. H form heavy-oil engines; Mawen 9A 9-cylinder 165-hp. and 7A 70-hp. rotary engines; Potez 12D 12-cylinder flat engine giving 450 hp. at 3000 meters and other smaller engines, and Potez engine auxiliaries groups including a pumping system; Regnier 4D 70-hp. and other sizes; Renault 12R 12-cylinder 450-hp. inverted vee and other engines; Salmson 12Vars 12-cylinder 450-hp. inverted-vee, 5AP.01 5-cylinder 85-hp. radial and other engines; Train engines; Boitel *Soleil 5-cylinder radial; and Polymecanique *Motobécane 35-hp. two-cylinder horizontally-opposed engine. Characteristics and performances of some engines are given in tables along with the descriptions. *L'Aéronautique*, January, 1939, pages 3–42, many illus., many tables.

A German 50-Hp. Unit. Zuendapp four-cylinder inverted inline engine develops 50 hp. at 2300 r.p.m. and 55 hp. at 2550 r.p.m. Fuel consumption 0.48 to 0.53 lb./hp-hr. Width 350 mm. Weight complete with air-cooling chute 132 lb. Brief description. *Flight*, February 16, 1939, page 160c, 1 illus.

Marcel Bloch Engines. Bloch 4A-1 4-cylinder engine of four liters per cylinder weighs 100 kg. and gives 100 hp. at 2300 r.p.m. Bloch 6B-1 6-cylinder engine of 6.5 liters per cylinder produces 180 hp. at 2300 r.p.m. and weighs 160 kg. A 12-cylinder inverted-vee 450-hp. engine has been designed which will be equipped with the same cylinders. Smaller engines are briefly described. *Les Ailes*, January 26, 1939, page 7.

Military Engines. M. Golovine. Armor protection is recommended for inline, V, or H aircraft engines, radiators, propellers, and cockpits. Information on the latest Rolls-Royce vee-type liquid-cooled engines including the Merlin II, Merlin X, and Peregrine, and a nomogram for quick estimation of theoretical full-throttle ground powers, according to output at a given height, are given in the original publication. Some data on the Peregrine and figures for the Merlin R.M. 2S.M. two-speed supercharged engine operating on 100-octane fuel are given in this review. From "Some Notes of Modern High-Performance Engines," a Rolls-Royce publication. *Flight*, February 2, 1939, page 105.

Recent European Developments in High-Speed Diesel Engines. P. M. Heldt. European aircraft and passenger-car Diesel engines are described. *S.A.E. Jour. (Trans.)*, February, 1939, pages 77–84, 12 illus., 1 table.

"Unitwin" Power Plant. M. Short. By use of an over-running, or "freewheeling" clutch, a power plant of two or more independent engines may be so assembled that they form a team to drive a common propeller through freewheeling clutches. This is the principle upon which the Unitwin power plant, consisting of two 260-hp. Menasco engines, operates. Safety or reliability factor of the freewheeling power plant is illustrated by a comparison of the probability of engine failure of a conventional engine with that of a Unitwin type power plant, when arranged on a single-propellered airplane. Advantages, development, and testing the Unitwin are also discussed in detail. *Aero Digest*, February, 1939, pages 55–56, 59, 7 illus.

Power Checked at Take-Off and at Altitude for the Principal Military Engines Mounted on First-Line Airplanes. Characteristics and performances are shown in a table for the following military engines: High-powered engines—Bramo 323, Pegasus XX, Hercules, Allison, Gnôme Rhône 14 N.2, Hispano-Suiza 12Y.21 and 14A.A., Mercedes-Benz D.B. 600, Napier Dagger VIII, Rolls-Royce Merlin II and IV and model with two-speed supercharger, Pratt and Whitney Twin Wasp, and Wright Cyclone 105-a.

Medium-powered engines—Hispano-Suiza 14-Ab and 12-X, Gnôme Rhône 14-Mars, Pratt and Whitney Twin Wasp Junior, and Rolls-Royce Peregrine.

Engines modified to operate on 100-octane fuel—Hispano-Suiza Y.51, Rolls-Royce Merlin RM2SM, and Pratt and Whitney Twin Wasp. *Les Ailes*, February 9, 1939, page 8, 1 table.

Props and Power Plants. Examples of American propellers, engines, and cowling are illustrated in photographs. *Aviation*, February, 1939, pages 30–31, 12 illus.

Technical Efforts of the Société Nationale de Construction de Moteurs. M. Victor. A 24-cylinder four-row radial engine of 1600 hp. and a 12-cylinder inverted 600-hp. engine will be turned out before long. The 24-cylinder engine is liquid cooled and composed of four six-cylinder radials. It employs direct gasoline injection, operates at 3000 r.p.m., and for a start will develop 1600 hp. Diameter is only 1.10 meters.

The 12-cylinder engine is an inverted water cooled in the form of a rectangle less than 50 cm. wide. It also uses fuel injection and operates at 3500 r.p.m. A two-speed supercharger is being tested and the Planiol-Schilowsky supercharger for which the company has acquired the license, is being produced. Only a few details are given for these engines, most of the article dealing with reorganization of the company. *Les Ailes*, January 26, 1939, page 8.

"Unitwin" Power Plant. M. Short. Two 260-hp. Menasco engines are the basis of the Unitwin power plant. A free-wheeling unit is arranged on the crankshaft of each engine and the gears forming the outer races of the freewheeling units serve to drive the propeller shaft gear. Free-wheeling principle is described. *U.S. Air Services*, March, 1939, page 36, 1 illus.

PARTS AND ACCESSORIES

An Aid to Starting. Rotax low-tension energy-transfer booster coil system makes use of a separate induction coil which is connected to the primary of the magneto. Coil has a self-operated magnetic interrupter. Primary winding of the coil is correctly proportioned to the battery voltage and secondary winding is designed to transfer maximum amount of energy at the most suitable voltage to the magneto primary. It is then stepped up by the secondary winding to produce a shower of sparks. Timing is determined by opening of the magneto contact-breaker and sparks persist until points close again. *Aeroplane*, February 8, 1939, page 190, 1 illus.

The Hirth Roller-Bearing Crankshaft. Built-up type of roller-bearing crankshaft and clutch designed by A. Hirth are described in detail. Among the illustrations are the web and pin assembly for a twelve-cylinder-vee-type aircraft engine, an attachment of the propeller hub to the shaft, and application to a rotary engine. Roller bearings permit this type of shaft to be run at speeds up to 8000 r.p.m. and it is possible to mount a gear wheel at any point on the shaft for auxiliary drives. Three methods of joining the crankpin to the webs are illustrated and discussed. *Engineering*, February 10, 1939, pages 154–155, 10 illus.

Aircraft Engine Accessories. Directory of manufacturers of aircraft-engine accessories is given with photographs of some accessories. *Aviation*, February, 1939, pages 60–61, 71, 75, 21 illus.

Inertia Starters. G. Broulhiet. Advantages of torque damper over slipping clutch, and mathematical analysis of the ultimate distribution of energy given to the flywheel in the cases of an inertia starter fitted with slipping clutch and of an inertia starter with resilient mass in place of the clutch. The latter type, designed by the author has a rubber disk as a resilient mass. Layout of the starter as applied to aero engines is illustrated and data and test results with the Type 14,500 starter are given. *Flight, Aircraft Engr. Sup.*, February 23, 1939, pages 5–7, 5 illus., many equations.

Synchronizing Aircraft Engine Speeds. Hamilton Standard automatic propeller synchronizer is intended to keep all engines running at the same speed. Description with photograph showing equipment for installation in a two-engined airplane and drawing giving schematic wiring diagram. *U.S. Air Services*, March, 1939, page 26, 2 illus.

A Supercharger with Controllable Pressure. M. Victor. Supercharger designed by Szydlowski and Planiol realizes the variation of pressure ratio without useless waste of power and without heating the air inducted. Aerodynamic calculation of the forms of the vanes in the supercharger has permitted it to attain practically the efficiency of 80 percent. Long description of supercharger and results of tests with the Hispano-Suiza 12Y engine at Chalais Meudon. *Les Ailes*, February 2, 1939, page 7, 4 illus.

Rockets

Experimental Rocket—Model 1939. J. H. Wyld. Author's conception of a Model 1939 experimental rocket approaching Pendray's "practical rocket" as nearly as possible, and under construction at the present time. Rocket is of the tail-drive type, gyrostabilized and carefully streamlined, being 9 ft. long, 5 in. in diameter, and cylindrical, with a long ogival nose, conical tail fairing, and four elliptical tail fins with movable rudders. *Astronautics*, February, 1939, pages 11–14, 1 illus.

Annapolis Motor Tests. Midshipman R. C. Truax. Report on research at the U.S. Naval Engineering Experiment Station. Motor used was similar to that used in December tests but modified by substituting a refractory-lined nozzle for the previous water-cooled one. Test apparatus and results of tests in regard to design and nozzle materials are discussed, and design of a flying rocket built for the purpose of solving control and weight problems is described. *Astronautics*, February, 1939, pages 6–10, 1 illus., 1 table.

Report on the 1938 Rocket Motor Tests. J. Shesta, H. F. Pierce, and J. H. Wyld. Proving stand No. 2 is described and illustrated and results of tests on various rocket motors are discussed including: tubular Monel motor with several ignition schemes and built by H. F. Pierce; a modified Pierce motor; Wyld tubular regenerative motor; and Truax tubular regenerative motor. *Astronautics*, February, 1939, pages 1–6, 3 illus.

What Can We Expect of Rockets? J. R. Randolph. Gunless artillery and long ranges are discussed as possibilities of rocket development. A brief theoretical analysis of the rocket is given, and R. H. Goddard's work in the development of rockets is referred to. Problems considered include: getting the rocket started in the right direction; production of an explosive that will have a stable burning rate at pressures around 1000 lb./sq.in.; and accuracy of the rocket. Germany and Soviet Russia are said to be doing a great deal of work on the first problem.

Air warfare is said to be just the type of service for which the rocket is least suited. It is thought, however, that it might prove possible against large targets to combine a rocket and bombing plane in such a way that the rocket carried the plane to the target and then was abandoned. *Army Ordnance*, January–February, 1939, pages 224–227, 1 illus., 2 tables, equations.

Aircraft Radio

Aero Radio Digest. RCA's new radio equipment including: AVA-41 trailing antenna system featuring flexible fairlead, easy installation, and communication on the ground; the AVT-15 transmitter supplied with the AVA-41 antenna system and AVA-31 microphone; the AVR-15 receiver; and the AVA-39 antenna loading coil designed to operate in conjunction with the AVA-24A antenna change relay. A $\frac{1}{4}$-in. flexible coaxial transmission line, Type 600, developed by Communication Products, Inc., using spun glass as the insulating medium between outer sheath and axial wire. Western Electric new lightweight superheterodyne receiver Model 25A intended primarily for private fliers. Radio Frequency Laboratories' Model T-3 10-watt aircraft transmitter for private pilots. Breeze short-wave radio direction finder for aircraft and ground use. United Air Lines static suppressor for aircraft use manufactured by Bendix Radio Corp. Market position protractor now standard equipment on American Air Lines flagships. Brief descriptions of this equipment, and abstracts of five reports issued by C.A.A.'s Radio Development Section, describing C.A.A.'s ultra-high-frequency receiver with wide continuous range and ultra-high-frequency marker beacons. *Aero Digest*, February, 1939, pages 86, 89–90, 7 illus.

Automatic Navigator. J. A. McGillivray. Arrangement of two linked automatic direction finders operating continuously and simultaneously indicating the position of the aircraft by intersection of a pair of pointers pivoted on a chart. Long descripiton. *Wireless World*, January 26, 1939, pages 76–78, 4 illus.

Aviation Radio 1939. Absolute altimeter developed jointly by United Air Lines and Bell Laboratories. M.I.T. blind landing system. Development by the Civil Aeronautics Authority of course markers and airport boundary markers operating at 75 Mc., traffic control and radio range beams at 125 Mc., and a superheterodyne with 5 microvolt sensitivity and a continuous tuning range from 60 to 132 Mc. Sperry and RCA radio direction finder operating on 350–450 kc. beacon band and completely automatic in operation. Descriptions of radio equipment. *Electronics*, January, 1939, pages 10–14, 43, 9 illus.

Present Trends in Radio Services. H. M. Samuelson. Ground radio station duties in Europe are discussed, including point-to-point service, meteorological service, ground-to-air service, navigational services, and close approach and landing aids. New blind-landing system made by Le Matériel Telefonique in Paris and to be installed at Le Bourget is described. For glide-path definition an entirely separate transmitter is used operating into a horizontal aerial system and giving a flat line of descent. Landing beam beacon and aircraft receiver can be added to an existing blind-approach system of Lorenz or Telefunken type. *Flight*, February 2, 1939, pages 106–109, 6 illus.

Radio for Safety. Photographs of radio equipment for aircraft, and short descriptions of Air Tracks' "Sky Track" inductor compass, RCA lightweight transmitter and receiver for the itinerant pilot with a unique reel antenna, and Breeze short-wave direction finder. *Aviation*, February, 1939, pages 64–66, 19 illus.

Receiving Conditions in the Arctic. I. M. Hunter. Data on long-distance short-wave conditions obtained on the Wordie expedition to West Greenland. One of the objects of the expedition was to examine variation with altitude of cosmic radiation near the geomagnetic pole, and automatic radio transmitting apparatus was sent to great heights (20 km.) by means of free balloons. Radio apparatus was used to investigate some of the electrical properties of the lower regions of the stratosphere. *Wireless World*, February 2, 1939, pages 111–112, 3 illus.

The Sectorial Electromagnetic Horn. W. L. Barrow and F. D. Lewis. Electromagnetic horn offers unique possibilities as a directive radiating system for microwave applications, by virtue of its unusual freedom from secondary lobes and stray radiation, its ability to operate well over a broad band width, its simple construction and ease and stability of operation. An electromagnetic horn radiator, two of whose opposite sides are flared, the other two being parallel, was studied experimentally at wavelengths between 40 and 100 cm. For comparison, measurements on parabolic reflectors and broadside arrays were also made. These results and application to a straight-line blind-landing system for airplanes are discussed. Research at M.I.T. *Inst. Radio Engrs. Proc.*, January, 1939, pages 41–50, 13 illus., 2 tables.

A Sense-Finding Device for Use with Spaced-Aerial Direction Finders. R. A. Fereday. Method for rapid determination at the receiver of the sense of direction of arrival of radiation from any transmitting station. Radio bearing of the station is taken in the usual manner with a four-aerial Adcock direction-finding system, and a second observation of minimum received signal is made after certain modifications to the electrical connections between aerials have been effected by switching. Two observations are sufficient to determine without the usual ambiguity of 180° the bearing of the transmitting station at the receiver. Method is particularly suitable for use on high frequencies and with the visual type of receiver incorporating a cathode-ray tube. *Instn. Electrical Engrs., Jour.*, January, 1939, pages 96–100, 6 illus., 1 table, 6 equations.

Some Principles in Aeronautical Ground-Radio-Station Design. P. C. Sandretto. Problems of adjacent-channel interference encountered when the air-transport industry established numerous voice radio circuits. Early solutions to this problem and later investigations and equipment corrections necessary are described. *Inst. Radio Engrs. Proc.*, January, 1939, pages 5–11, 13 illus., 1 table.

Theory of the Electromagnetic Horn. W. L. Barrow and L. J. Chu. A theoretical anlysis of the operation of the electromagnetic horn "antenna" is derived from Maxwell's equations. Details apply to a horn of sectoral shape. Analysis also applies to a tapered hollow-pipe transmission line. Certain transmission quantities, like the phase constant, attenuation constant, velocity of propagation are calculated for horns of any angle flare and the field configuration within the horn is plotted. Calculations of radiation patterns made in this analysis agree satisfactorily with experiments reported in a previous paper. *Inst. Radio Engrs. Proc., January*, 1939, pages 51–64, 14 illus., 40 equations.

Photography

Aerial Photography with Automatic Equipment. R. Henrard. The Richard Labrely planiphote described is automatic and may be operated by the pilot while he is flying the airplane. It is constructed with three focuses according to the altitude used, 30 cm. (200 to 2000 meters altitude), 50 cm. (2000 to 5000 meters), and 70 cm. (5000 to 10,000 meters or more). A $\frac{1}{10}$-hp. electric motor is employed to unroll the film and operate the shutter. Long description of equipment used by the Armée de l'Air. *L'Aérophile*, November, 1938, pages 255–256, 3 illus.